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SHE puts up her hair with a plastic comb; surveys herself in a plastic mirror; a plastic bracelet on her wrist; bright plastic buttons ornament her dress. She is one of a generation rapidly becoming plastics conscious. She realises that war-time demands have curtailed the output of the charming plastic novelties, trinkets and household devices that once captivated her, and sometimes she wonders what we have in store for the future . . . What have we? . . . We have years of experience of plastics research and development, an up-to-the-minute knowledge of the new trends and methods speeded up by war-production and a first rate range of plastics products already well-established. If you have plans that include the use of plastics we shall be pleased to advise you.

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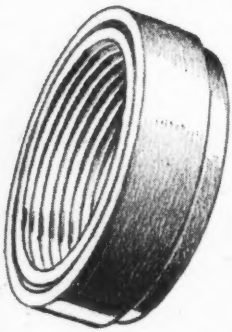

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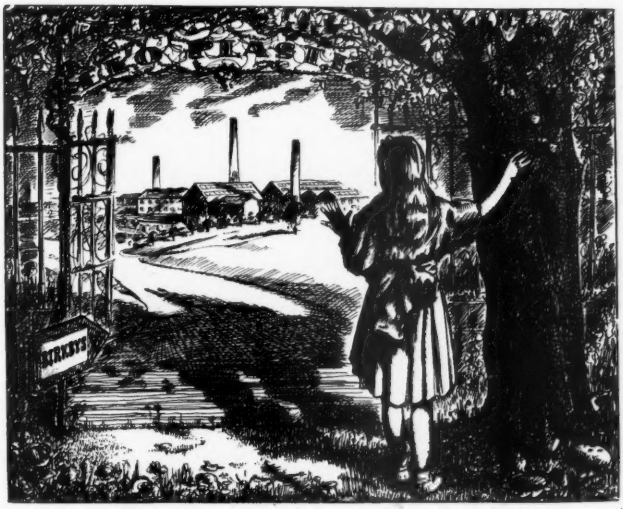

Alice comes to a Factory

There sure enough was that word again, Elo. Elo Plastics. Where had Alice seen it before. Of course. In the catalogue she was reading before she went to sleep. And here it was again over an arch, and through the arch what seemed to be a factory. Of course this must be the Elo factory . . . . It looked just like the drawing on the front of the catalogue.

It lay across the horizon of Alice's vision, spreading North, South, East and West . . . . not a severe formal sort of factory, but a friendly looking place that seemed to invite closer investigation. The looking glass had nothing on this, thought Alice, being ever so slightly Americanised and walking forward under the Elo Arch right up to the factory itself.

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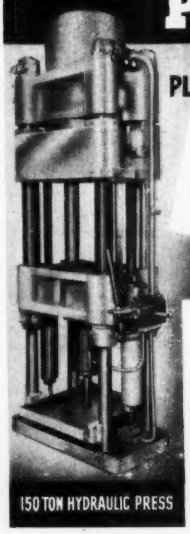

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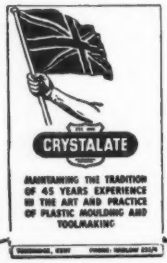
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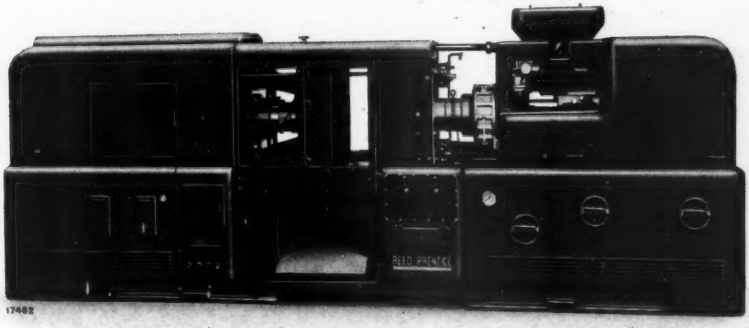

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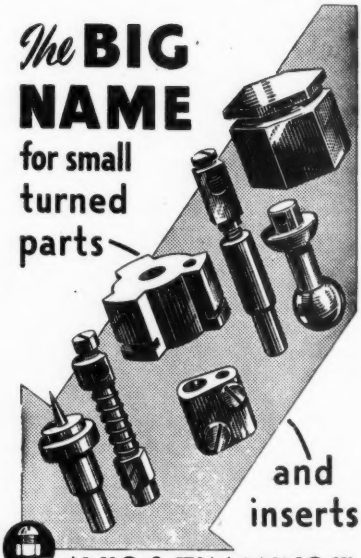

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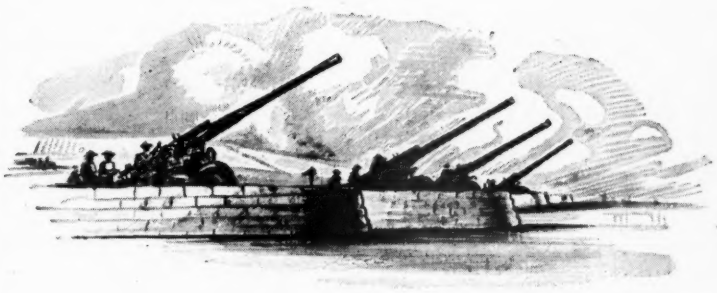

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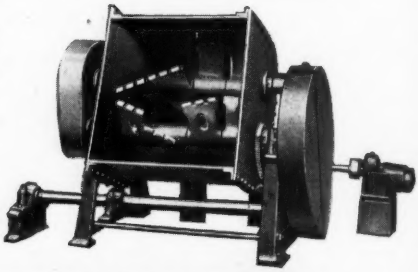

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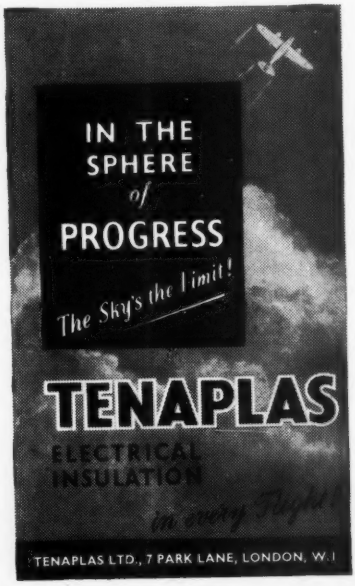

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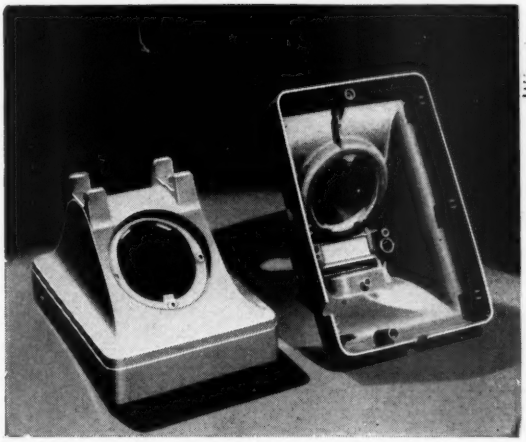

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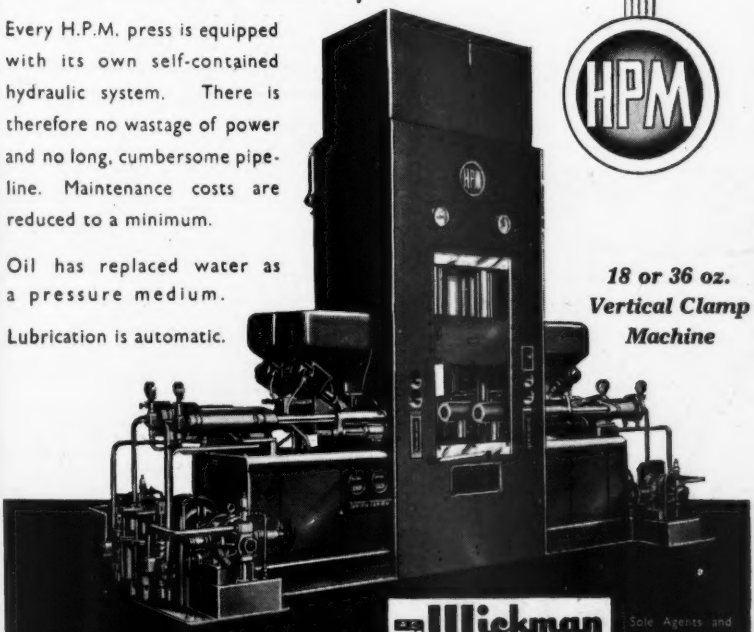

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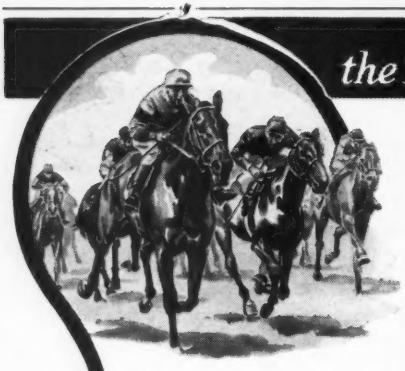

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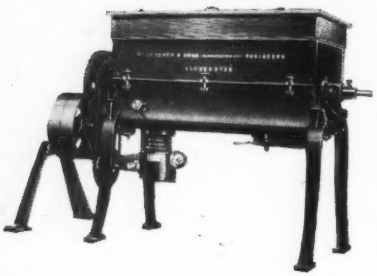

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Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

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CONTENTS

	Page
Editorials	200
Metallizing Plastics, by E. E. Halls	204
Theory and Practice of Electrical Insulation ..	209
World's Industry Employs Plastics	214
High-frequency Heating, by D. Warburton Brown, A.M.I.A.E.	218
Behaviour of Plastics at Elevated Temperatures ..	227
New Process of Making Moulds by Electrodeposition, by P. Spiro, B.Sc. ..	229
Lacquered Aluminium Wire	232
Production News	235
Planned Mould Maintenance Service, by W. M. Halliday	237
Resinoids and Other Plastics as Film Formers, by B. J. Brajnikoff	246

NOTICES

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SAVE PAPER

More than ever is paper waste required for our war industries. Waste paper makes munitions in a hundred forms—from shell cases to aeroplane parts.

The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Softwood into Hardwood

THE treatment of timber with synthetic resin as distinct from the treatment of plywood veneers is not a new experiment and most nations in the world have endeavoured to solve the very difficult problems involved.

From the United States comes the information that Du Pont de Nemours have succeeded in treating softwood with a "compound of urea and formaldehyde" transforming it into what may be termed hardwood.

The news has arrived in this country in a garbled form and with some surprise we note a correspondent of "The Yorkshire Post" writing the following rubbish:—

"I have to-day been given an enthusiastic account of what will follow America's discovery of the effect of a formaldehyde solution upon softwood. The discovery, I was told, would enable Britain to be rebuilt in a year—provided, I presume, we had the wood and the labour.

"When the softwood houses were ready for occupation the sprayers would get to work and under pressure send the solution right through the grains of the wood. When everything had been thoroughly soaked the house would be allowed to dry. In the drying a complete plastics building would gradually be formed. The formaldehyde solution would have spread over the wood its natural resinous content. The wood would have become harder than iron. It would be impossible to knock a hole in it anywhere.

"Damp, noise or heat could not pass through the walls. It is even claimed that a traction engine running into a wall would bump off, not go through."

Even "The Times" forgets itself and describes the new process as making "wood nearly as hard as steel." The claim, reported in the same journal, that the cost is 3½ to 4½ cents a foot super requires confirmation, or at least coupling up with a statement regarding the quantity of resin impregnated.

It is now nearly 20 years ago that we acted as honorary observer of the earliest English experiments that were carried out at the Ramsay Laboratories at University College in Gower Street by that brilliant chemical engineer, the late Professor W. E. Gibbs and Mr. B. J. Brajnikoff, who had recently come from the United States, and first saw their pilot vacuum impregnation plant made, we believe, by George Scott and Sons, Ltd., of Silvertown. It was a most fascinating piece of work, and we remember then first learning of the vagaries of wood and of the difficulties which arise in trying to push a viscous material into a porous but not altogether water-free structure and then to cure it, or, alternatively, of the difficulty of producing resins in wood by impregnating water-soluble phenols in the presence of incompatible organic compounds.

The death of Dr. Gibbs, followed by the destruction of much plant in a bomber raid early in the war, put an end to the work at the Ramsay Laboratories, but the problem has not been shelved altogether. The success of Du Pont's once again rouses general interest in the subject. The possibility of using "green" timber would in itself be a major revolution, for we can readily calculate how much time and space would be saved if, instead of maturing wood for anything between three months to two years, we were able to send it out to the various industries in a few days. Furthermore, there arises the possibility of utilizing woods of very inferior grades, such as Belgian lime, bastard willow, jarrah, plantation cuttings, and so on.

While our earliest interest in the subject, for some strange and forgotten reason, was in the production of improved and "everlasting" pit-props which no mine-owner would have bought because of cost, it has veered round to a variety of applications, ranging from wooden roof tiles to building structures for tropical usage. The conversion of cheap timber to greater strength, water-proofness and resistance to wet and dry rot and to the ravages of insects would prove an immense boon to the world at large.

Much of the problem is obviously bound up with the cost of synthetic resins and their availability. Both cheaper resins and new resins, or rather new sources of resins, are urgently required, for unless the process is confined to special applications, enormous quantities will be in demand.

Vacuum treatment of wood is not a cheap process, and one wonders if a process could not be devised whereby the wood is "killed" by a hot pressure treatment with a water-soluble urea or phenol and formaldehyde mixture followed by an external treatment with a resin. If the removal of water could be made unnecessary and if the water could be "fixed," cost would be lowered considerably. Alternatively, it seems not unreasonable to imagine a first impregnation with a cheap impregnant followed by a second producing the desired highly resistant outer skin.

J. J. Berliner and Staff

ONE of the most important services that can be rendered to workers in scientific and technical fields is that of supplying abstracts of papers published throughout the world.

Several institutions exist for this purpose, and for what is generally a modest annual sum the scientist can find on his table a useful list of short abstracts from journals relating to the subject in which he is interested.

He can then, by buying the individual issue referred to, obtain all the fuller details he requires for the furtherance of his special studies.

J. J. Berliner and Staff, of Fifth Avenue, New York, is one such institution which does this—and much more; perhaps we should say much more to the benefit of J. J. Berliner (possibly not Staff). Some months ago we received a postcard from this concern stating that it was issuing a special report on the subject of Metallizing Plastics. Our readers may well imagine how interested in this subject we are, since we had published, commencing in June, 1943, and have completed in this the current issue, a very important and detailed analysis of the whole subject by Mr. E. E. Halls, an Englishman working on the problems here in London, Eng.

We therefore ordered with considerable alacrity a copy of their report, and on its receipt were asked to pay the sum of £3 16s. 3d. in exchange. Now, this price is not too high for an important technical report. But we found it too high for our purpose and too tough for our gullets when we discovered that, with the exception of a small tailpiece, it was lifted, word for word and table for table, from Mr. E. E. Halls's first three articles in the June, July and August issues of "Plastics."

This may be very flattering to us, but on no page and in no hidden corner was any reference made of the source of this information. In fact, on the very expensive cover is a statement: "A Berliner Research Survey on New Development in Metallizing Plastics." Apparently Research Survey in Berlinese means the copying of other men's work, using the well-known apparatus made by the Roneo company.

The irony of it all is that for this arduous task J. J. Berliner and Staff get £3 16s. 3d. for each copy, while all the proprietors of "Plastics" got for the three issues of "Plastics" was 4s. 6d. and had themselves to pay £3 16s. 3d. to see the same in typescript.

Perhaps J. J. Berliner and all his Staff are taking the principles of the Atlantic Charter too literally.

High Vacuum Distillation for Plastics

DURING the last few years a new technique of industrial distillation has grown up, which bids fair to affect the whole of the chemical industry, and with it the production of plastics.

Normally the bulk of chemical "high" vacuum distillations for the production of so-called purified substances was carried out at about 1 mm. pressure or slightly under. To-day industrial plant is available for work at one-thousandth of this pressure, that is, 10^{-3} mm. or 1 micron.

A valuable paper on this subject has appeared in a recent issue of "Chemical and Metallurgical Engineering." It describes some of the technical advances that have been made in diffusion pump construction and the many industrial possibilities of the process. So far the only large-scale plant being used is in the metallurgical sphere for producing magnesium. On a small scale there is considerable production of vitamin concentrate.

In the chemical field the possibilities for high vacuum distillation include heat sensitive materials, which decompose at high temperatures; and materials of extremely high molecular weight, such as the higher alcohols, fatty acids, drying oils, waxes, plastics and other high molecular weight organics which formerly were not distillable. At the pressures heretofore available it has been possible to distil fatty acids up to C_{18}, but by means of presently available pressures of about 1 micron, or slightly less, the corresponding tri-glycerides in the molecular weight range up to 300 can be fractionated, and, in fact, compounds as high in chain length as C_{30}, and molecular weight up to 2,000 or higher, can be distilled. Under high vacuum, with properly designed stills, an adequate separation of compounds differing by 20 per cent. in molecular weight is possible, and awaits only the development of suitable large-scale distilling equipment of performance comparable to that at present obtained with laboratory high-vacuum distillation apparatus.

Some work has been done on the fractionation of high melting waxes and much promise for the improvement of drying oils exists in the use of high vacuum distillation to permit removal of lower molecular weight compounds present in the oil. A large field for the exploration of the possibilities of extreme low pressures is the petroleum industry which at present is limited to pressures no lower than about 10 to 20 mm. The new technique offers possibilities for cost reduction through elimination of cracking, and for the development of new products and the improvement of existing ones, such as the manufacture of many materials to much more rigid specifications than are now feasible.

By its means we shall be able to produce polymers with a really close range in molecular weight, learn more about their properties, and select closer groups for their individual characteristics.

Raw Materials

SOME few months ago, as our readers no doubt remember, we gave it as our considered opinion that the petroleum supplies of the United States were rapidly drying up and that we had better confine ourselves in the main to plastics from coal and plastics from other natural resources which latter renew themselves from year to year in a most benevolent manner. Our views have been confirmed since by many experts, and by the intensive search for petroleum in hitherto unexplored countries.

Last month we had a visit from one of the bright lads in the motorcar industry and we fell to discussing this problem of petroleum. "With luck, you know," he said, slyly, "you may not need to worry about petroleum; there may always be plenty of it for plastics." "Elaborate," we said, so he went on: "Well, certain motorcar manufacturers are doing some amusing work on electrically driven cars with very interesting results. Already one

or two have been running round the country at over 30 m.p.h. for 50 miles without recharging, and already somebody in Australia has claimed to do 100 miles at 40 m.p.h. on one charge. You may yet see the end of the petrol stations and in your journey to the north just knock at somebody's door and ask to plug in for a few pennyworth of juice."

So there you are. This is a serious business and we must revise our ideas.

If this invention is successful there will be plenty of petroleum for the chemical industries throughout the world to play with, and we come again to the question of real petroleum refineries in Great Britain. We understand, on going to press, that the Anglo-U.S. discussions on oil are progressing in a state of harmony. We hope that our experts at the meetings will insist on participation in the production of chemicals and plastics from this source.

From the United States come other ideas of raw materials. Dr. William Hale, a research consultant, forecasts that in 20 years the alcohol industry may involve a production of 20,000,000,000 gallons and that the cost should be less than 10 cents a gallon.

Ethyl alcohol in these quantities for industry would indeed be interesting, for from it we can make chemicals of the first importance to plastics and synthetic rubber. Indeed, the curious situation has arisen in the U.S.A. that whereas ethyl alcohol as a source of butadiene for Buna was howled down by the petroleum-producing industry, much more synthetic rubber is being made from alcohol than was budgeted for.

As Dr. Hale so rightly pointed out, there can never be an over-supply of farm output once industry makes full use of this production through the fermentation industry.

Budget Relief

SIR JOHN ANDERSON may well go down to financial history as the patron saint of small business-men.

Many small concerns, begun in pre-war days, and working at a very low profit or, indeed, in the "standard period" with most of its resources devoted to development and industrial research, incurring anticipated losses, were in the invidious position of existing under conditions of crushing taxation. To add to the rage of such concerns, especially if they were producing for direct or indirect important Government contracts, many companies well established before 1936, but producing luxury dresses, jewellery, handbags, cosmetics and the like, are protected by taxation relief. To-day some 30,000 small businesses benefit in that all their standards (where they are minimum standards) are increased by £1,000.

Aiding Research

THE Chancellor did not stop here in his help to industry: he not only saw the benefit of giving financial assistance by making a special initial allowance of 20 per cent. of the cost of plant and machinery, but also the necessity of giving aid to industrial research.

His proposal was that in capital research expenditure, normal expenditure on laboratories, buildings, plant and machinery would be allowed over a period of five years, or for the life of the asset, whichever was the shorter, as a deduction from profits for income-tax purposes. Expenditure on salaries, wages, cost of materials and repairs would also be allowed.

This allowance would be the rule for research carried out by a trading concern on its account. In addition, any payment, whether for capital purposes or as a contribution to a central research body approved by the Department of Scientific and Industrial Research, would be allowed as and when made as a deduction in computing profits. Contributions to research carried out by universities or colleges would similarly be allowed.

We are grateful for such concessions. They are important, but we await Government decisions regarding really big expenditure by itself for research.

D

Metallizing Plastics
(continued)

A Complete Survey and Critical Study of the Modern Methods of Metal Film Formation on Plastics for their Protection and Decoration

by
E. E. HALLS

Miscellaneous Additional Information and Summary

Although this treatment of the subject of metallizing plastics has been extended over a number of issues, and may have appeared to be comprehensive, it has not been exhaustive with respect to methods, nor in so far as processes within one method are concerned. Again, finality has not been reached in any sense. In closing the article—but not the subject—a few features that have been omitted can be included with advantage.

Relevant to the processes described under Sections 1 and 2, viz., metal powder coatings bonded with organic media, attention is called to the coating procedure covered by British Patent No. 433218. This claims the application of a synthetic resin adhesive solution followed by spray application of metal powder. The process is thus similar to the well-known flock-spray, in which adhesive is applied and then coated with flock, which may be one of numerous types (e.g., cellulose acetate silk, viscose silk, cotton, wool, etc.). The patent mentions an oil-modified glyptal adhesive of the following composition:—

Glyptal resin, tung oil type	43.88 lb.
Naphtha	53.13 lb.
Cobalt linoleate ...	2.99 lb.

This adhesive is applied by one of the usual processes and then sprayed with the powdered metal. The coating is burnished before the varnish has completely dried, and then baked to harden the varnish.

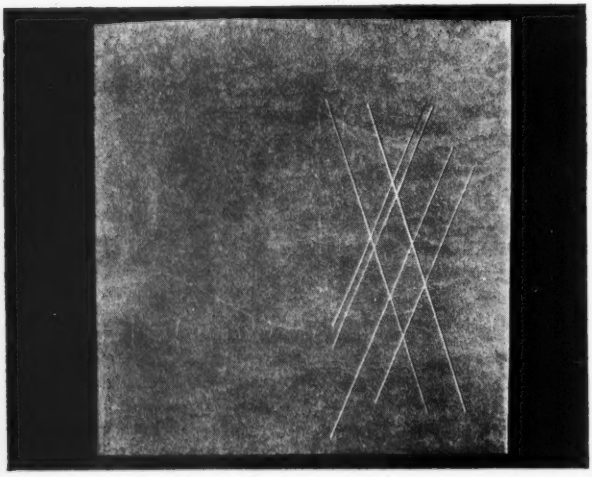


Fig. 36.—Methacrylic resin sheet, zinc sprayed by the powder pistol method, after exposure to cycles of dry heat. The metal coating shows excellent adhesion.

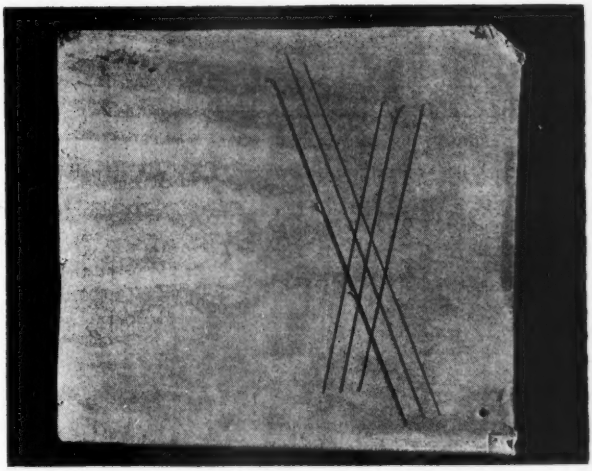


Fig. 37.—Polythene sheet zinc sprayed by powder pistol method after exposure to cyclic dry and wet heat tests; showing excellent adhesion of metal coating.

This type of process has possibilities for yielding electrically conductive films.

Small articles of suitable shape can be treated by the organic media processes in barrels. Thus, with the metal powder media, it is sometimes possible to barrel treat, it being necessary, however, to judge the exact amount of coating material required, and preferably to use a barrel in which the temperature can be raised to dry off the coating gradually before removing the articles from the barrel.

The barrel procedure, too, should be practicable with the method mentioned under the above patent number.

Reverting to the metal-sprayed coatings proper that were dealt with under Section 3, and queries concerning adhesion on the newer thermoplastic materials, it can be asserted that this is satisfactory, although, of course, it is a function of the physical properties of the two materials, the plastic and the metal, particularly hardness. For example, the acrylic resin plastics, which usually present highly polished hard surfaces, need roughening by light abrasive blasting in the usual manner. No. 40 or 60 crushed steel shot is quite suitable for this purpose. Fig. 36 shows a panel of 0.080-in. thick opaque acrylic resin sheet sprayed with zinc by the powder process and then subjected to corrosion tests. The latter consisted of a dry cycle at 71 degrees C. for 6 hours, cooling off in the oven, then a moist cycle of 6 hours at 60 degrees C. and 95 to 100 per cent. humidity, again cooling off in the test cabinet, and, finally, a repetition of this moist cycle. Naturally, some whitening of the zinc surface occurred, but no serious deterioration resulted and no loss of adhesion, which was excellent. Fig. 37 shows a panel of zinc-sprayed polythene sheet similarly processed and tested. Again, adhesion was good and the test proved its serviceability. The scratch lines on the samples, made after completion of the test, demonstrate the soundness of the adherence of the metal coatings in the case of both materials. Naturally, the " apparent " adhesion of the coating on polythene is of lower order than that of the metal spray on the acrylic resin sheet. This is due to the softness of the former, and, on scratching through the coating with the thumbnail, it is the actual base material that flakes away. The actual average thickness of zinc on these specimens was 140 mgms. per sq. in., of the order of 0.0018 in. actual thickness value.

While for these actual specimens the powder pistol was employed, equal results can be obtained, using the wire or molten-metal methods. It is considered that these methods have extensive application for metallizing partial areas of plastics, particularly the low loss electrical grades for reason of capacity or capacitance. Silver as the coating metal is exceedingly useful for such requirements at high frequencies.

Somewhere, probably under Section 4 or 6, mention should have been made of the cast clear phenolic resins having metal powders (coppers, aluminium, etc.) dispensed in them, the object being useful for decorative effect.

Under Section 5, attention can now be called to some of the new adhesives, that is, those of the Ardux and Redux types, the phenolic cements with separate acid hardeners, especially the organic acid varieties of the latter, and the rubber-base adhesives which utilize a special priming coat followed by the adhesive proper, with which has to be incorporated a separate vulcanizer.

Possibly under Section 7 should have been included a reference to many "printing" processes. The latter refer to the use of metal inks, viz., normal printing inks having a metal powder pigment that are applied by roller or pad, and give very attractive finishes of design or print. Inks of this kind with good properties of electrical conductivity have, so far as we know, yet to be produced. Also under this heading should be included a number of "printing" processes which use paint or enamel as the printing media, and can therefore use metal-pigmented media. The Selectascine process for application through a mask, and the gelatine transfer process for application from an engraved master, are illustrative. These processes are applicable to any base material and are excellent for plastics of all types. Details of these marking or printing processes would extend this article too far and are really a field on their own.

With respect to the three American patents mentioned in connection with the electro-plating of plastics, the following is a brief summary of their claims and process features.

No. 2,214,646, May, 1938, is due to B. F. Walker, of the Metaplast Corporation of New York. It claims a method of ornamenting the surface of a plastic material by sandblasting, so as to depolish the surface, cleaning to free the surface from foreign matter, immersing in a solution of stannous chloride for 30 minutes to 1 hour in order to impart characteristics suitable for metallizing, then thoroughly washing to remove stannous chloride, then treating in a mixture of ammoniacal silver nitrate solution and a reducing solution so as to precipitate silver on the surface as an adherent metallic layer, and, finally, using this metallized layer as a cathode for electrodeposition. It also claims an article comprising the plastic material with a firmly adherent silver layer deposited thereon, and an electrolytically deposited layer on top produced in accordance with the first claim.

The patent does not go into details on process, but indicates that the invention relates to plastic materials, including hard rubber, phenolic resin products, urea resins, synthetic resins in general, cellulose plastics or materials coated with them. It makes a major point of the treating of the surface of the plastic material in order to depolymerize a portion of that surface. This is the primary object of the stannous chloride solution. It does point out that some of the steps specified may be omitted depending on the condition of the material and the nature of the coating required. Thus the depolishing may be omitted on cast resins and thermoplastic materials if the metallized coating is to be the finished surface; or if only a thin plating is to be applied, which will not have the strength to be peeled from the surface; or, again, an extremely heavy plating which in itself would have the strength to resist the tendency to peel. Part surface may be treated.

No. 2,063,034, April, 1932, is due to Eric Freund and it refers to methods of

producing metallic coatings on cellulose esters or like materials. The chief claims may be summarized as follow:—

(1) Production of a silver coating on cellulose nitrate by treating the surface with a saturated solution of potassium dichromate in sulphuric acid having a specific gravity of about 66 degrees Baume, this then being diluted approximately four parts to one part of water. The material is then rinsed to remove acid and neutralized with a basic solution containing a tin salt, then precipitating silver on the surface from the silvering solution, finally drying and lacquering.

(2) The use of a similar solution of potassium dichromate and sulphuric acid of 60-70 degrees Baume without dilution.

(3) The amalgamation of a small quantity of mercury salt with the silver after the silver coating has been formed.

(4) The application of these processes to cellulose esters.

(5) The application of these processes to cellulose acetate, having treated the surface of the latter first with cellulose nitrate.

The patent mentions the following acid composition as mainly satisfactory:—

Sulphuric acid 66 degrees Baume ...	100 cc.
Potassium dichromate	15 grams
Water	25-30 cc.

The plastic is immersed and removed from the bath before the solution can do more than superficially attack the surface. It is then rinsed quickly in distilled water and treated with a basic solution. For example, sodium carbonate, bicarbonate or hydroxide. By following this with a tin solution, improved adhesion of the silver is obtained. It is claimed that any silvering solution can be used, and one particular satisfactory one is cited, viz.:—

(a) 14 grams of silver nitrate in 100 cc.s of water.

(b) 8.3 cc.s of 0.880 ammonia in 100 cc.s of water.

(c) 4 grams of potassium hydroxide in 100 cc.s of water.

(d) 3.5 grams of rock candy, 12 cc.s of alcohol and 10 drops of concentrated nitric acid in 200 cc.s of water.

Solution (d) is boiled for about 10 minutes and, after cooling, is diluted to replace one-half of the solution lost by boiling. Also an additional 10 drops of nitric acid are added. A mixture of equal parts of the four solutions is thoroughly shaken together and immediately poured over the surface of the work to be silvered. When the silver is all deposited, the sheet is dried, presumably after rinsing in water. The silver, if to be employed as the final operation, has to be protected by clear lacquer or by moisture-proof membrane. There is a natural yellowish tinge to the deposited silver which can be corrected by a further operation of treating in a solution containing a small amount of mercury. A preferred solution is as follows:—

Potassium cyanide ...	1.25 grams
Mercuric cyanide ...	1.25 grams
Water	50 cc.s
Dilute to	6,500 cc.s

About 5 seconds' immersion is required.

The application of the thin film of cellulose nitrate to cellulose acetate is to eliminate the possibility of forming silver acetate which gives a yellowish tinge to the silver coating.

No. 2,010,805, November, 1932, is due to Max Ow-Eschingen. It claims a process for producing dense adherent metal coatings on finished articles produced from materials of a colloidal basis and including casein, albumin, glue and gelatin by introducing into the material a swelling agent containing an aromatic amine reducing agent. The object is to produce in the surface of the finished article, without interfering with its production, a reducing agent which, when the article is immersed in metallic salt solutions, will precipitate the metal on the surface of the article.

It also claims the immersion of articles of this series of base materials immersed in a mixture of hydroquinone and methyl p-amino-phenol dissolved in alcohol and water, which acts as reducing agent.

The patent refers to already known methods for rubber articles consisting in etching with and without the addition of a reducing agent to the mass, and claims to extend this to other plastics by using suitable solvents and swelling agents in conjunction with reducing agents. An example is given of a casein product in a polished condition immersed in 3-4 per cent. solution of hydroquinone in water. It is then thoroughly dried and placed in a metallic salt solution such as a silver solution. The immersion process is repeated three times and a coating obtained which can be highly polished by rubbing.

With casein, water is a suitable solvent or swelling agent, and besides hydroquinone, p-aminophenol or p-phenylenediamine are suitable reducing agents. With the albumins, water is also a suitable solvent and amino aromatic compounds are suitable reducing agents, for example, p-amino-phenol or p-phenylenediamine. Phenol condensation products require acetone as a swelling agent and a mixture of hydroquinone and catechol or pyrogallol as reducing agent. Water solutions of hydroquinone are suitable for urea and thiourea products, but they have to be used almost boiling. For glue and gelatine materials solutions of hydroquinone plus methyl p-amido-phenol in equal parts of alcohol and water are used. An example is given of phenolic product immersed for three to five minutes in a solution of four parts of hydroquinone and one part of pyrocatechine in 100 parts of acetone. It is then thoroughly dried and immersed for about two minutes in a 2 per cent. solution of silver nitrate at 80 degrees C. The deposit of silver produced adheres firmly and can be reinforced by repeating the immersion several times.

An example of urea products is given, viz., 2 minutes in a water solution of 4-5 per cent. hydroquinone at 90 degrees C. The article is dried and immersed for 1-2 minutes in a 2 per cent. solution of silver nitrate at 80-90 degrees C. One immersion is usually sufficient.

Electro-platings for all types of plastics are interesting radio engineers for screening and capacity reasons, but in many of these applications it is felt certain that vacuum evaporation will be the final answer when further development work has been completed.

Again, it is stressed that this treatment of the subject has not been exhaustive. While it is dangerous to indicate outstanding processes or a general trend, it can be asserted that metal spray proper is an established general purposes utility procedure for metallizing plastics. Electrical sputtering and evaporation should automatically come into their own when commercial advancement overtakes modern radio development. Metal-coated sheets, with various metal types and thickness on various types, quality and thickness of plastic, will ultimately compete with metal-sprayed sheet and strip material. For decorative work, particularly that from which short service life only is demanded, the printing processes will cater effectively.

Plastic Buttons

One wonders what will be the condition of the button industry in this country after the war. In his statement to the shareholders of Lacrinoid Products, Ltd., the chairman, Mr. Horabin, described the improvements that had taken place and hoped that the company would be in a position to export after the war.

There is a vast scope in this country alone, since only 20 per cent. of our requirements were made here, the remaining 80 per cent. being imported from Germany, Italy and Japan. We now have the opportunity to take the whole of our market. Not only has the casein button been long established here in the factories of BX (Plastics) and Erinoid, Ltd., in addition to Lacrinoid, but we appear to have experts in the corozo nut button, including the so-called "secret" dyeing process, which was presumed to be the prerogative of the Italians. Furthermore, moulding from urea resins, polystyrene and methyl methacrylate has gone ahead.

Theory and Practice of Electrical Insulation

The Technical Application of Non-conducting Media, more especially Plastics, is Considered in the Light of Chemical and Physical Properties and with respect to Service Requirements for Cable Insulation (after Heering, "Elektrotechn. Zeitschrift," 1942/63/439)

INSULATING materials may be considered as forming inactive parts of electrical machines, instruments, cables, conductors, etc., as they do not participate at the actual conduction of energy. In spite of this, however, they constitute an indispensable part of the conductor technique; they are expensive, take up valuable space, and accumulate heat which must be dissipated. For these reasons it is necessary that their bulk be as small as is reasonably possible. Thus there is an urgent demand for insulating materials with optimum electrical and mechanical properties.

The following account deals with the physical principles of insulation, a property which enables a material to resist the passage of an electric current, in spite of the fact that the materials consist themselves, like all other matter, of molecules and atoms involving complex electrical forces.

In contrast to metals, which are monatomic, solid and liquid insulating media are composed of molecules, e.g., combinations of many atoms. This statement does not apply to gaseous insulating materials, but, on the other hand, in the gaseous condition, any difference between metals and non-metals virtually ceases to exist. In the case of solid insulating materials, very high molecular weights are of common occurrence.

Whereas inter-atomic linkages can be broken down only by the application of very great energies, molecular linkages may exhibit all degrees of stability from very strong to very loose and labile. For insulating materials, stable molecules are to be preferred and are usually, in practice, essential.

Of the two types of linkage, ionic and non-polar, the latter is advantageous from the standpoint of insulation in that atomic nuclei share a common electron orbit. This type of linkage is frequent in organic compounds. The ionic or polar linkage occurs in the case of salts of strong acids, for example, sodium chloride. Compounds of this latter type disassociate with great readiness, particularly in water, a property most undesirable in the case of insulators.

Of the whole periodic system with its 92 elements, 72 are of a metallic nature and must, therefore, be excluded, right from the beginning, as insulating materials. Of the remainder, only two have found extensive application (in the form of compounds) as the basis of insulators, viz., carbon in the case of organic insulators and silicon in the case of inorganic insulators. This is a general statement, and exceptions may be found. For example, certain complex phosphorous compounds, elementary sulphur and some metallic oxides are, or might be, useful insulators. Metallic oxides, incidentally, are, in certain cases, unique in that, if their powers of insulation are not particularly high, they are, at least, maintained at very high temperatures. For example, note the use of oxidized nickel-chromium wire in heating elements consisting of closely wound helices.

Carbon compounds and silicon dioxide possess the power of forming substances of the high molecular weight characteristic of insulating materials. Silicon

dioxide, in the form of quartz or crystobalite, may be considered as an ideal case of a single giant molecule and is the basic type of most inorganic insulating materials. Its opposite number is the diamond, which may be considered as the basic type of organic insulating media. The diamond can be regarded as a giant molecule in which every constituent carbon atom is strongly linked to its neighbour. Both quartz and diamond are characterized by high chemical inertness and great mechanical hardness. The high hardness of the diamond is a consequence of the form and stability of its lattice.

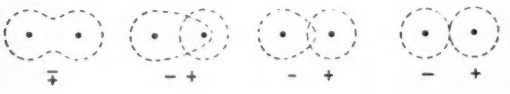


Fig. 1.—Ionic and non-polar linkages according to Fajans. Extreme left—ideal ionic linkage. Extreme right—ideal atomic linkage, with non-polar properties at maximum. Centre diagram—transition forms.

All organic insulating materials based on carbon have, unfortunately, severe limitations as to thermal stability. In practice, such organic materials may undergo particular types of ageing characterized by the very slow absorption of oxygen, with correspondingly slow diminution in their insulating properties. Partial replacement of carbon by silicon in organic compounds of this type has been shown to increase resistance to thermal decomposition, whilst introduction of other elements, for example, sulphur into rubber, diminishes liability to ageing.

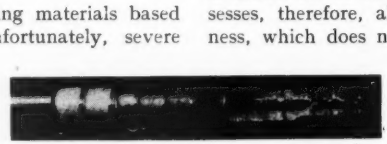


Fig. 2—Cable for television transmission, insulated with flexible polystyrene in tape form.

Not only chemical composition but also the size of the molecule will govern the electrical, mechanical (and chemical) properties of an organic insulator.

Three different spacial arrangements of the atoms in a complex molecule are possible, viz., the chainlike, the two-dimensional form, and those types built up of atoms distributed in all three dimensions.

Materials of fibrelike molecular structure, both organic and inorganic, natural and synthetic, are of special importance. To this group belong cellulose, the polyamides (nylon), natural and synthetic rubber, and some inorganic materials, such as asbestos.

Amongst inorganic insulating agents, mica is typical of the two-dimensional form. The three-dimensional form is typified in the inorganic field by quartz and diamond, and amongst representative organic insulating materials the phenolic resins are well known. Glass wool also has a three-dimensional sub-structure which is not lost even when the material is drawn out to the finest gauges; it possesses, therefore, always marked brittleness, which does not interfere, however, with its processing into woven form as a special insulating material.

In the accompanying table are set out representative insulating materials classified under the headings "Organic" and "Inorganic," and considered in the light of their optimum mechanical and electrical properties. It

Fig. 3.—Heat resistance of natural rubber mixes and Buna mixes. Solid line—heat-resistant Buna ss. mix (25%). Broken line—heat-resistant natural-rubber mix (25%). Dotted line—normal natural rubber (25%).

is not to be inferred that, for any given use, one or other of these materials may or may not be interchanged with its neighbours; it is clear, however, that, in many cases, synthetic materials are now available equivalent in properties to naturally occurring materials and, in some cases, showing advantages over these latter. For example, the break-down strength of cellulose triacetate foil is superior to that of the impregnated paper commonly used for paper insulation; the tensile strength of Perlon fibre is superior to that of natural silk, whilst impermeability to water is more marked in the case of Oppanol than in the case of paraffin. In two respects, naturally occurring materials are superior to most synthetics; thus natural rubber possesses extremely high elasticity, whilst the water absorption of paraffin is practically negligible. It is as well to remark here that, of the manufactured insulating materials, many grades are possible, each type being, as a rule, designed to fulfil some specified purpose.

The use of plastics in electrical engineering is so extensive to-day that this science cannot be conceived as existing without their presence.

Plastics for insulating purposes may be produced by the polymerization of pre-existing molecules of smaller size, by condensation, or by a combination of both of these processes. The most striking of all the polymers from the electrical standpoint is polythene, produced by the direct polymerization of simple ethylene molecules. It is characterized by its high electrical resistivity, low dielectric loss and low dielectric constant. In structure, it resembles the paraffins, but is superior to them in mechanical properties at elevated temperature. It may be readily formed into any desired shape by injection moulding and may be extruded around a conductor. It may also be rolled out into foil form.

Table 2.—Optimum Values of Organic Insulating Materials.*

Main characteristic	Unit	Natural substance, improved		Synthetic substance	
			Optimum value		Optimum value
High specific resistance	Ω. cm.	Paraffin Amber	10^{17} —	Polystyrene (Trolitul) Polystyrene (Lupolen)†	10^{17} 10^{14}
Low dielectric loss	tan δ	Paraffin Amber	10^{-4} 10^{-3}	Polystyrene (Trolitul) Polystyrene (Lupolen)†	10^{-4} 10^{-3}
High break-down strength	kV/mm. at 50 c/s	Impregnated paper	61	Triacetate foil	180
Low dielectric constant	—	Paraffin	2.2	Isobutylene (Oppanol)	2.3
High dielectric constant	—	Cellulose fibre	5.8–6.0	Clophen†	5.0
High tensile strength	kg./sq. cm. g/den.	Wood Silk	800–1,000 3.5–4	Laminated wood (Lignofol) Synthetic albumin (Perlon silk)	1,000 5.0
High elongation at fracture	%	Natural caoutchouc mixture	700	Polybutadiene (Buna mixt.)	650
High rebound elasticity	%	Natural caoutchouc mixture	65–75	Polybutadiene (Buna mixt.)	55–60
High resistance to prolonged heating	°C.	Cotton	90	Triacetate foil	90
Heat resistance according to Martens, °C.	—	—	—	Vinyl polymerisate (Luvican) phenol-formaldehyde	100–150 130–170
Small water absorption	% (97% humidity)	Paraffin	0.005	Polystyrene (Trolitul)	0.03
Small permeability to water	$\frac{10^{-8}\ g}{h.cm.mm.Hg}$	Paraffin	0.06	Isobutylene-graphite mixture (Oppanol)	0.01

* According to H. Heering, "Electrotechn. Zeitschrift," Vol. 63, 1942, pp. 439-442.
† Composition not known.

Polystyrene produced by the polymerization of monomeric styrenes has long been on the market. In electrical properties it may be considered to approach polythene, although its mechanical properties differ markedly. By extension in the heated state some degree of molecular orientation appears to occur and a strong bendable form is obtained. (See Horn "Kunststoffe," 1940/30/53 and "ETZ," 1940/61/902.)

Polythene and polystyrene are now finding extensive use as insulating materials for high-frequency conductors. Polystyrene is used in the form of simple threads, twisted threads and tapes. The use of polythene and polystyrene insulation may be considered as having rendered possible many of the latest developments in television and allied techniques.

Although in many ways not remarkable for its electrical properties, polyvinylchloride, marketed in Germany in various grades under the generic title Igelite, finds extensive use on account of its superior mechanical properties, which, for electrical purposes, frequently render its use in place of natural rubbers desirable. Cables insulated with polyvinylchloride need not necessarily be cotton braided, an additional protection which is necessary in the case of rubber insulation. Secondary advantages resulting from this are decreased possibility of water absorption at the exterior surface of the insulation and diminished friction, which otherwise arise when pulling a cable through a conduit, or when movement of any kind should take place. Polyvinylchloride is extensively used for the insulation of telephone field cables, and it is gaining favour as an insulator in domestic wiring where it replaces rubber in the familiar "cab tyre." Polyvinylchloride insulators may be safely operated within the temperature range of -5 degrees C to $+50$ degrees C.

Polyisobutylene is prepared for use in electrical industries in a wide range of molecular weights. Thus, with a molecular weight of 2,000, this material exists as a thin oil with excellent dielectric properties superior to any of the natural occurring petroleum products.

This grade of polyisobutylene is used in U.S.A. as an addition to lubricants, particularly for I.C. engines, to guard against the effects of decreasing viscosity at high temperature and, to some extent, to prevent deterioration due to crankcase dilution.

With progress in polymerization, a cable insulating oil marketed in Germany as Oppanol B4 is obtained. When a molecular weight of 15,000 is reached a honey-like material of high viscosity, known as Oppanol B15, results; this is employed as an adhesive for insulating tapes. With still higher molecular weights a solid insulator, Oppanol B100, results; whilst, finally, Oppanol B2,000 is an elastic, rubberlike material. Further variation is mechanical, and electrical properties can be obtained by co-polymerization.

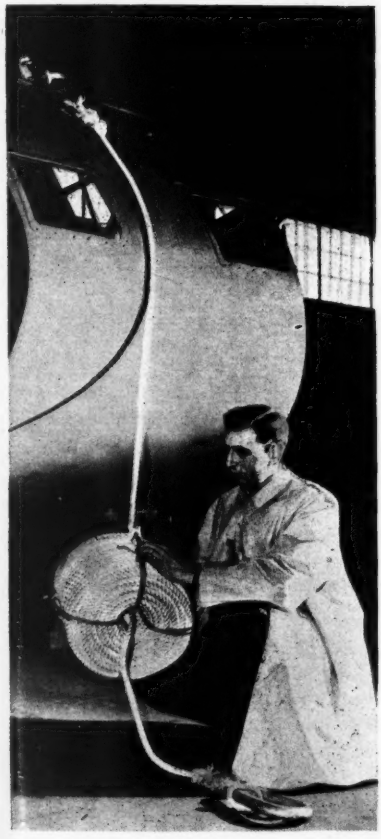
So much for the plastic bases themselves. A further possibility of varying properties consists in the addition to the bases of various organic and inorganic fillers. Thus Oppanol, which already exhibits in the unfilled form the lowest permeability to water of all the rubberlike organic compounds, is further improved in this respect by the regulated addition of special grades of carbon black. One grade of polyisobutylene so filled is so highly impermeable to moisture that it actually may be used to replace lead sheathing on cables, although, here, some additional mechanical protection is required as the material is, by itself, not sufficiently wear resistant.

Much has been written on the chemistry and properties of natural rubber and rubberlike films. Of the so-called synthetic rubbers, those marketed under the trade name Buna in its various forms are of principal interest in the light of the present discussion. Of particular importance here are the co-polymers of butadiene with styrene (Buna A) and with acrylic nitrile (Perbunan). Perbunan is highly resistant to mineral oil, and both Buna A and Perbunan have high heat resistance. For this reason, these rubberlike materials may be used where natural rubber cannot be employed; for example,

in cables laid in ships' holds where high temperatures are to be expected, Buna insulation is permissible. Armature-end coverings may consist of Buna mixes in place of the normal lacquered cotton tape. Buna S and Perbunan are also employed for insulating telephone conductors and high-voltage cable.

Of plastics of the long-chain type analogous in many ways in composition to protein, the polyamides claim first attention. Fischer laid the foundations of this work in the early days of the 20th century. The development by Carruthers of nylon completed the work which Fischer began and carried it to its present commercial stage. The polyamides, suitably treated, have superior mechanical properties, excelling in this respect the finest natural products, not excepting silk. It should be pointed out, however, that, as regards electrical properties, the polyamide plastics are somewhat inferior to natural silk.

Nylon for Pick-up Mail Services



While it is common knowledge that nylon rope is being used successfully for the towing of aircraft, the fuller uses of the new fibre, which depend on certain unique characteristics of the material, are not so well known in this country.

Non-stop air-mail service is now common in the United States; the authorities have adopted nylon rope, replacing manila and steel cables heretofore employed.

Picking up mail by aircraft in flight is made with a 10-ft. pole which sticks out beneath the aeroplane and holds the hook in position for the "strike" as the pilot swings down over the ground station. Contact of the hook with the mailbag rope starts the winch drum turning and paying out the line. This has the effect of accelerating the mailbag gradually from a dead stop until it attains the speed of the aeroplane and trails after it. An electric motor then reels in the mail.

Nylon rope has proved excellent for the job. The tensile strength of a $\frac{1}{4}$-in. diameter rope is about 3 tons, or approximately twice that of manila rope of the same thickness. Reports on its abrasion resistance, determined by rubbing the rope back and forth over a smooth metal bar, were much delayed—because the nylon took so long to wear out. After a million rubs it was still good, while manila wore out after 200,000 rubs. Coupled with numerous crude but practical tests, the Du Pont investigations indicated nylon would be ideal for the pick-up work.

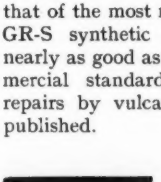
Nylon obviates the need for mechanical shock absorbers, since it performs this function smoothly and efficiently. Although the pick-up takes only a second or two, the actual contact is imperceptible.

World's Industry Employs Plastics

MOTORS

Canada's demand for tyres is said to be covered by the output of the Polymer Corporation with its new plant in Ontario. This is producing Buna S and butyl rubber (''Canadian Machinery,'' 1944/55/81). The article is well illustrated and production charts are included. **Plastic "grit"** has been turned to account by the United States Air Force for removing carbon from piston walls and piston grooves. The "grit" is used in place of sand or steel shot as in ordinary sand-blasting operations (''Automotive and Aviation Industries,'' 1944, Feb./90/88). A vinyl-type plastic, Marvinol, recently developed in U.S.A., has previously been noted in these columns. It is said to have higher temperature resistance than the normal vinyl plastics and apparently does not undergo breakdown in strong sunlight or when in contact with dilute acids or alkalis. These properties, it appears, are conferred by the use of a special non-extractable plasticizer. The material was developed in the Martin's Plastics Research Laboratory, and has already demonstrated its superiority to natural rubber and synthetic rubbers for automobile inner tubes and allied purposes. **Comper,** a flexible, rubber-like material, is said to be 5-20 times more wear-resistant than natural rubber and to be more resistant to solvent action than any rubber substitute yet developed (''Scientific American,'' 1944/99/79). **Rates of wear of five different tread materials, including pre-war natural rubber,** for private-car tyres have recently been determined by F. L. Roth and W. L. Holt, of the National Bureau of Standards (Research Paper RP 1574, Feb., 1944). The rate of wear of the least resistant tread material was eight times that of the most resistant material. Type GR-S synthetic rubber appears to be nearly as good as natural rubber. A commercial standard, CS 110-43, for tyre repairs by vulcanization, has just been published.

GENERAL ENGINEERING



Lucite cap for protecting thread when chromium-plating pistons for landing gear is described by McDaniel in ''The Machinist,'' 1944/88/96. Plating time is said to be reduced by half as a result of this practice. **Wet grinding process** for production of a laminated phenolic resin spool is said to have overcome many manufacturing difficulties. Tolerances had to be held down to $\pm$ 0.0005 in. The first grinding operation is performed on a special centreless grinder with cam operation for the regulating wheel. The MM-60 wheels are diamond dressed after the lathe operation on a capstan; slots are ground on a modified surface grinder at a peripheral speed of 6,000 ft./min. Lubrication is by means of water with 5 per cent. cutting oil, the swarf coming off as a fine flour suspended in the coolant (''The Machinist,'' 1944/88/97). **Celluloid guards** for sensitive Sheffield electric gauging heads have been made by L. Berg. They are designed to prevent tampering with adjustments. Three heads are protected by a single guard, which is easily formed and joined at the sides after cementing with an acetone

solution ("The Machinist," 1944/88/99). **Metal-bonded diamond wheels** are recommended by the Precision Diamond Tool Co., Chicago, 2, Illinois, for the precision grinding of plastics. This appears to represent a new application of this type of grinding wheel. **Wire strain gauges** of the electrical-resistance type form the subject of research recently undertaken by the N.P.L. Nichrome wire, 0.001 in. in dia., is wound upon a loop of thin resin-impregnated paper, thermosetting cements or thermoplastic cements being used to fix the gauges to surfaces. An account of these gauges was given by Aughties before the Institution of Mechanical Engineers. Clenshaw reported at the same meeting the results of experiments on the brittle lacquer technique and its limitation for stress determination; "Stress-Coat" lacquer of the Magnaflux Corporation of America was employed for this work. **Ball-bearing retainer rings of Micarta** made by Westinghouse have the required mechanical strength, coupled with light weight for high-speed bearings. They have been installed on grinding spindles running at speeds as high as 60,000 r.p.m.; such rings gave about 15 months of continuous service. **Production of plastic from potato-starch residues** has been investigated by Idaho National Farm Chemurgic Council. Tests show moisture absorption within limits suitable for many commercial uses. Flow characteristics permit moulding. Shrinkage can be controlled and appears to be within acceptable limits. Metal inserts cast into the plastic remain firmly embedded. A commercial proposition is V-belt pulleys of potato-pulp plastic, to which sweet-clover fibre is added (Ralph E. Gale in "The Chemurgic Digest," reproduced in "Scientific American," 1944/99/124). **Report of the Association of German Engineers (VDI)** shows that plastics are being utilized technically to an ever-increasing extent, as their specific properties may readily be adapted to specific purposes. In order to assist the engineer to apply plastics correctly, a number of recommendations have been issued, a nearly complete list is as follows:—**VDI 2,001 design of components of thermosetting materials,** a new edition contains tolerances for parts provided with screw threads. **VDI 2,004, recommendations for roller bearings of laminated textile material** (May, 1942), contains data on design, maintenance and most economic use of the laminated material, with suggestions to increase durability. **VDI 2,005, recommendations for the design of rubber gaskets.** Theoretically, sealing between metallic surfaces can be obtained easily when they are absolutely plain and smooth; practically, a gasket of flexible material should be placed between, which will accommodate itself to the roughness of the surface, but should have resistance to excessive deformation. Shape of the gasket and pressure depend on the properties of the rubber used, shape and surface roughness of the part to be sealed, and degree of internal pressure. For smooth surfaces the deformation path is small; for great roughness, softer rubber should be employed. It is recommended that lateral expansion be limited by placing the gasket into a groove. **VDI 2,006, recommendations for the design of injection moulded parts of thermoplastics.** This publication consists of 14 pages with 73 illustrations and 3 tables. **VDI 2,007, welding of thermoplastic material. VDI 2,008 deals with semi-manufactured materials of thermoplastic substances; and VDI 2,009 with foils and protective films of thermoplastics. VDI 2,010 deals with the design and construction of pipe lines of thermoplastic.** Further researches sponsored by the same committee are investigations with regard to the wear of plastic gears, the influence of the number of teeth, transmission ratio, etc. **A further committee dealing with technical problems in other countries and the colonies,** having the name "Akotech," formed as contraction of "VDI—Ausschuss der Arbeitsgemeinschaft Ausland und Kolonialtechnik," investigates the suitability of plastics in tropical countries and has

three sub-committees dealing with the thermoplastic, thermosetting and vulcanized materials. The establishment of such recommendations is linked up with a new organization known as "Unimap" (an abbreviation of a French name standing for International Technical Union of producers of plastics, or I.T.V.). One of the first problems set for this body is the international standardization of definitions, testing methods, types and control of production.

AIRCRAFT

Lightweight, strong plastic board, produced by U.S.A. Rubber Co., is used for forms to support bullet-sealing fuel cells. It is said to have half the weight of aluminium sheet and in relationship to weight, tensile strength and loading capacity compare favourably with metals. It is a non-conductor of electricity, has a high fatigue strength and is not affected by petrol, oil, blended fuels, acids, alkalis, alcohol and other solvents. The board can be bent, cut and formed ("Scientific American," 1944/99/86). **Minalith Process of American Lumber and Treating Co.** allows plywood to be made flameproof by the use of a combination of phosphate, sulphate, and boron chemicals. The new process is said to prevent spread of flames and delamination; the wood cells through the plies are filled with chemicals, thus inhibiting combustion of the wood substance. This new process, applied to aircraft hangar doors, may make plywood an outstanding material for post-war reconstruction. **New sound-deadening material, Vibeston,** on the basis of asbestos, is now used instead of mica, which is listed as strategic material. As it is 50 per cent. lighter than mica, greater use may be made of it in aircraft construction. After the war it may be useful in air-conditioning units where vibration and noise have to be suppressed. **Largest Saran part** is a 35-oz. injection-moulded mask for use in chromium-plating war-time aircraft landing gear struts. On a Watson-Stillman machine the moulding cycle is only 70 secs.

MISCELLANEOUS

Bonding of abrasive wheels by means of synthetic resins is covered in German patent 734,828. The abrasive grains are mixed with water emulsion of polyvinyl compounds, poured into a form or mould, dried out and finished by heating. The use of polythene for manufacture of collapsible tubes, waterproof coatings, piping adhesives and insulation for electric cable is described in "Automotive and Aviation Industries" for February 1, 1944 (page 42). The polythene referred to is manufactured by Du Pont de Nemours. **Properties and uses of all types of plastics** are covered in a new non-technical booklet on the plastics industry issued by the Richardson Co., U.S.A. The publication is well illustrated. **Hermetically sealed plastic wrapping** for protecting machine parts in shipment and storage has been developed by the Dow Chemical Co. The protective covering is an ethyl cellulose-base plastic applied by hot dipping at 350-375 degrees F. A tough, skin-like coat is formed, protecting the part from corrosion and dirt; it is easily stripped. No degreasing and cleaning are required, and in this respect alone the new system is definitely superior to the use of grease and paper wrapping ("Machine Design," 1944/Feb./16/140). **Strain analysis methods,** using brittle lacquers, have been described by Hetenyi and Young of Westinghouse Research Laboratories. First experimental work was undertaken in Germany during 1932, but recently a superior

cutting material, "Stress-coat" has been developed in U.S.A. The author's account contains excellent illustrations of structures investigated showing stress zones and weak spots. A single test permits the detection of maximum stress, its location and direction, but numerical data require a number of co-ordinated tests. The tendency to use the brittle lacquer method for qualitative tests only to locate danger spot, accurate tests being afterwards conducted by strain-gauge methods ("Machine Design," 1944/Feb./16/147). **New sealing cement,** "High-Pyseal," has been developed by Fischer Scientific Co. The new sealing cement has a higher melting point than Pyseal itself, which was brought out to replace the German product, Picein cement. Ring-and-ball softening point of Pyseal is 58 degrees C. and of High-Pyseal 80 degrees C. In use, both parts of the joint to be sealed must be heated ("The Laboratory," 1943, No. 1/14/14). **Natural rubber of improved fire-resisting properties** is said to have been developed by Wakabayashi, who employs in the mix special fillers in conjunction with a synthetic resin. The work is said to be under the general direction of Professor Nitta of Osaka Imperial University. **Lip microphone** for the U.S.A. Signal Corps uses fine washers of bonded glass fibre pressed into wafer-like mats. These are produced by the Owens-Corning Fiberglas Corporation ("Scientific American," 1944/99/60). **Litho plates of polyvinyl alcohol** save from 3-8 times their weight in strategic metals, such as aluminium and zinc, and give approximately the same number of impressions as metal plates. They carry about 25 per cent. more ink without smudging (Scientific American," 1944/99/77). **The evolution of the U.S.A. synthetic rubber industry** and accounts of the personnel responsible for its growth are given by Killefer in "Scientific American," 1944/99/58. **Storage of micro films** forms the subject of recommendation recently issued by British Standards Institution (B.S. 1,153-1944). The use of acetate film is strongly recommended; containers with round seamless slip lids for rolls of 35-mm. film in 80-100-ft. lengths are standardized. Desirable atmospheric conditions for storage have been investigated by the National Bureau of Standards, U.S.A. **Breast plates** of durable plastics for the protection of women workers have been put on the market by a U.S.A. firm. The curved plates are supplied in three sizes and extend well back under the arms to prevent injury to the lymphatics; ventilation is provided (Wilson Products Inc., Reading, Pennsylvania). **All-plastic goggles** in Plexiglas, which are designed to fit directly over prescription glasses, have recently been permitted by the U.S.A. War Production Board. A fully extended frame gives added protection against injury from the sides, top and bottom. Lenses can easily be removed for cleaning or replacement. The frame is strongly reinforced with metal clips at the bridge and is amply ventilated ("Canadian Machinery," 1944/Feb./55/106). **Saran screen innersole** is used for jungle boots and other military footwear. It is made up of several layers of Saran screen stitched or welded together at the edges. The soles are resilient, flexible and tend to ventilate the sole of the foot, and thus help to control fungoid infection. As Saran does not absorb moisture, the soles may be washed quickly with soap and water, petrol, etc. The same material is used for insect screening in hot, moist climates ("Scientific American," 1944/99/132). **For removing gummed paper from plastic glass sheets** (such as Plexiglas, Lucite, Plastacele, Acetate, Pyralin) and formed parts a new chemical compound has been developed (Turco Products Inc., Los Angeles). The components are simply soaked in a tank full of the compound until the gummed paper is loosened and is then easily peeled of. **"Plastics To-morrow"** is the title of the leading article in the March, 1944, issue of "Scientific American" (Vol. 99). Plastics, it says, are not to be regarded as substitutes. The industry must apply new techniques to fulfil post-war promises.

HIGH-FREQUENCY HEATING

By D. Warburton Brown, A.M.I.A.E.

Since the publication of Mr. Dring's and Mr. Zade's articles on high-frequency heating of thermosetting and thermoplastic resins respectively, we have been asked by many readers for information regarding the theory of the new method of heating. The author here deals with the subject in a concise and simple manner

WITHIN the last two or three years there have been many developments in the plastics field which have done much to increase the reliability of the product and to improve production. Of these by far the most important has been the adaptation of high-frequency electricity for heating purposes. The results obtained are remarkable, and in this article it is proposed to discuss not only the advantages which accrue from its use, but also to endeavour to explain the mechanics of the processes involved.

Before going into detail, however, it is proposed to deal with the subject in general terms and examine the methods which are now employed. High-frequency electricity can be used for heating purposes in two ways, first by induced eddy currents in the material to be heated. and secondly by using capacity currents. The first method is applicable only to materials which are good conductors and which have easily detachable electrons in their atomic make up. A typical example of the use of high-frequency eddy current heating is to be found in the " Tocco " surface hardening of steel. Another is its use for drying motor car bodies after spraying.

When dealing with insulating materials, however, the eddy current method is not applicable, and the capacity current method has to be employed. Examples of this method are to be found in the manufacture of plywood and in the pre-heating of plastic moulding powders.

In the plastics field the capacity current method will be the one which is used, since plastics are all comparatively poor conductors, that is they are good insulators. Briefly, this method consists of linking up two plates of a fixed condenser in circuit with a suitable form of high-frequency generator and using the material to be heated as the dielectric in the condenser. Generally speaking, valve oscillators are used as the source of high-frequency power.

The cause of heating in the condenser dielectric can be explained by several theories, which will be discussed in more detail later, but at this juncture it is sufficient to say that when using high-frequency, or heatronic, heating heat is generated within the bulk of the material, unlike the case where heated platens are employed. In the latter case heat must flow from the platen surfaces to the centre of the block of material, so that at the commencement of the heating operation there is a steep temperature gradient, the platens being at a temperature in the region of 300 degrees F., and the centre of the material at approximately room temperature. When the poor heat conductivity peculiar to all plastic materials is taken into account it will be appreciated that the process is not an efficient one. It is estimated that with steam-heated platens only 10 per cent. of the heat supplied is usefully employed in heating the material. Again, owing to the poor heat-transference properties the time taken to heat the material is considerable. To quote an example, the time which is necessary to heat a block of birch 6 ins. thick is about 20 hrs.

It has previously been mentioned that when using high frequency the heating occurs within the bulk of the material. This being so, the poor heat conductivity becomes an advantage rather than otherwise, since it tends to hold the heat within the material. In addition, heating proceeds uniformly throughout the material,

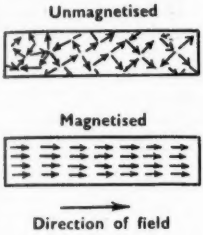


Fig. 1.—Arrangement of Weber elements in magnetic field.

and there is no serious heat gradient to be taken into account. A heat gradient can occur, but this will be dealt with in more detail later. The result of these factors is that the heating is very much more rapid, and referring back to the example quoted above for steam-heated platen, the time necessary to heat a 6-in. block of birch to gluing temperature using heatronic heating is only 25-30 mins., as compared with 20 hrs. An amazing time reduction, and one which has enormous potentialities in the production sphere.

The capacity current method has been applied with outstanding success in the manufacture of plywood and in the preheating of moulding powders in the normal moulding technique. It is also used for producing shaped parts built up from laminated wood, and will doubtless find an outlet before long in the production of laminated plastic sheets, rods and tubes.

The advantages of heatronic heating are manifold, but recapitulating them may be said to be:—

(a) For a given annual output the number of presses required will be substantially reduced, as will plant overheads.

(b) Idle time on presses will be minimized.

(c) Waste of material will be avoided.

(d) Uniformity of products will be obtained.

(e) Floor space and man-power will be reduced.

(f) More efficient heating will be obtained. Heat efficiencies of 50 to 60 per cent. are obtainable, as compared with 10 per cent. for platen heating.

Theories of High-frequency Heating

In the year 1845 Faraday discovered that all materials are feebly magnetic, and if subjected to a very strong magnetic field they tend to set themselves with their longer axis along the lines of force. That is, they are paramagnetic. Turning now for a moment to the molecular theory of magnetism as propounded by Ampire and later by Weber, it will be realized that a piece of magnetic material is composed of molecules each of which is in itself a small magnet. In other words, the material is built up of innumerable small magnets which in an unmagnetized state arrange themselves into positions of equilibrium, possibly in ring formations, under their own mutual action. In this condition the magnetic forces of the molecular magnets are more or less balanced out and the effect outside the material is nil. If, however, the material is placed in a magnetic field each of the molecular magnets, or Weber elements, as they are called, tends to take up a position along the lines of force of the applied field. Fig. 1 illustrates this diagrammatically. If the direction of the applied field is altered, the Weber elements will tend to

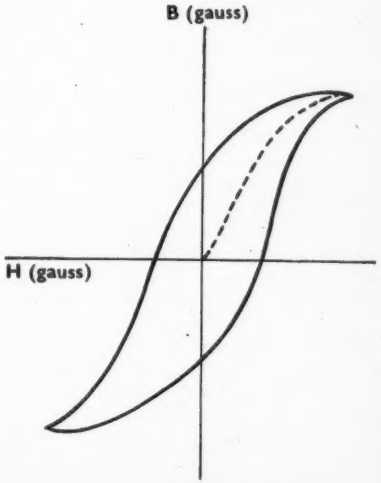


Fig. 2.—Hysteresis curve.

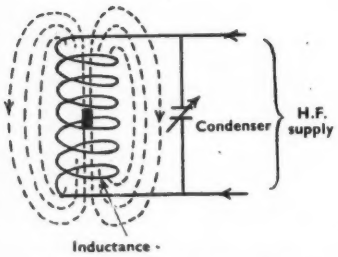


Fig. 3.—Lines of force in an inductance.

follow. Again, if the direction of the applied field is changed rapidly from one direction to another, the Weber elements or molecular magnets will be in a state of vibration whose frequency is that of the applied field.

It is now necessary to refer to the question of hysteresis. When the magnetizing force is removed from a piece of magnetic material which is near to its saturation point, the material does not immediately return to its original unmagnetized state, but retains a portion of its magnetism. Fig. 2 shows a typical hysterisis curve for a magnetic material. When the magnetizing force is released, therefore, there will be a balance of energy left in the material. Considering now the effect of an alternating field upon the Weber elements in a material, the elements will vibrate under the action of the field, but will be, to some extent, restrained from movement by neighbouring elements. In other words, there will be a balance of energy left in the material. This energy manifests itself in the form of heat within the material. If the rate of fluctuation or the frequency of flux change is high, the heat generated will be considerable. The greater the frequency the greater will be the rate of heating.

The molecular theory of magnetism described above was, later, more fully developed by Ewing, and satisfies the state of affairs which appertains to the induction heating method. Here the article to be heated is placed inside an induction coil through which alternating current passes. There will, in consequence, be lines of magnetic flux passing through the centre of the coil (Fig. 3). Change in direction of the flux will cause the Weber elements in the material to vibrate, the hysteresis effect causing heat to be generated.

The above theory does not, however, satisfy the case of capacity heating. (Refer to Fig. 3.) In the case of induction heating lines of magnetic flux flow through the material placed inside the coil. In capacity heating, however, the material to be heated is placed, not in the coil, but between the plates of the fixed condenser. Here the passage of high-frequency currents does not produce a magnetic field. Some other explanation for the heating effect must therefore be found. It is now accepted that the atom is composed of a positively charged nucleus, around which negatively charged electrons rotate on two or more orbits. The electrons on the outer orbit are the valency electrons, and it is these which are of importance. Langevin advanced the theory that the electrons spin round the nucleus in different directions, some in a right- and some in a left-handed direction. (See Fig. 4.)

Knowledge regarding the behaviour of electricity within non-conducting material is limited compared with that which is available for metals, gases and electrolytic substances. It is possible, nevertheless, to visualize the process which occurs. The dielectric (or the material to be heated) which is placed between the plates of the condenser is made up of atoms, each of which has electrons which are non-detachable, but which are, presumably, movable when subjected to an electro-motive force. It has been suggested that the EMF does

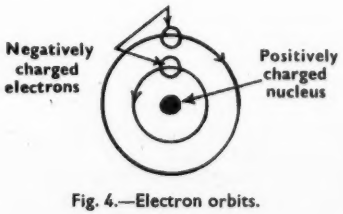


Fig. 4.—Electron orbits.

not disrupt the atoms in the dielectric substance, but merely distorts them on their orbit. Thus, electrons moving on a circular orbit might be made to rotate on an oval orbit when under the influence of an outside electro-motive force. This is illustrated in Fig. 5. The molecule as a whole is assumed to be fixed firmly in position by the neighbouring molecules

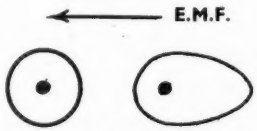


Fig. 5.—Distortion of electron orbit.

and that the only change is in the mean position of the electrons. If now the direction of the EMF is assumed to change, the shape of the electron orbit will change also. If the direction of the EMF alternates, the result will be a pulsation of the electron orbit.

If the frequency of the electron pulsation is sufficiently high it is conceivable that, due to some form of molecular friction, heat will be generated within the body of the material. This supposition satisfies the conditions appertaining to the capacity current method of heating. Each molecule behaves as a conducting particle, and when it is subjected to an EMF to the left it becomes positively charged, as it were, on the left, and negatively charged on the right.

Heat transference can occur in three ways:—

(a) By conduction.
(b) By convection.
(c) By radiation.

In the first, heat flows from bodies at a high temperature to one at a lower temperature. That is, a temperature gradient exists. Typical of heat flow by conduction is the placing of a cold body in contact with one which is at a higher temperature. Convection, on the other hand, is due to the currents set up in fluids or gases by the molecular agitation caused by thermal effects. Both cases of heat transference by conduction and convection follow Newton's law of heat flow, that is, the quantity of heat passing through a section of a material and at right angles to it.

$$Q = \frac{KAOT}{t}$$

where K = the coefficient of specific heat conductivity (calories/sec./sq. cm./°C./cm.).
A = area of cross section (sq. cms.).
O = time (secs.).
T = difference in temp (°C.).
t = thickness of material (cms.).

This relationship governs the heat flow between any two bodies in contact and has an important bearing upon the results which can be obtained using the high-frequency capacity current method of heating. It will have been appreciated, although it has not yet been stated, that the plates of the condenser are fixed to the plates of a suitable press, or to some other form of support. It has been pointed out that, owing to the nature of HF heating, heat is generated uniformly throughout the bulk of the material. If the material is clamped between the two condenser plates and these are at atmospheric temperature, there will be a fairly sharp temperature gradient between them and the outer sections of the material to be heated when this reaches the curing temperature, which is in the region of 300 degrees Fahrenheit. This will result in the outer layers of the material being at a lower temperature than the main body, hence unequal heating will occur. In other words, if the centre of the block of material is cured correctly, the outer layers will be in an under-cured state, and vice versa. In order to overcome this, it is obviously desirable that the condenser plates should be externally heated to a temperature approaching that of the final cure temperature.

Apparatus

All high-frequency heating depends upon the supply of high-frequency oscilla-

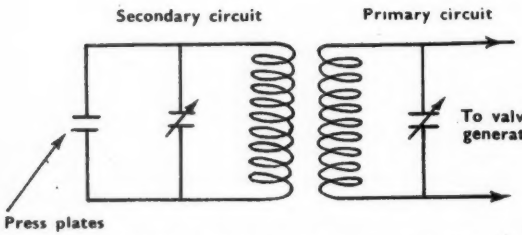


Fig. 6.—Diagrammatic arrangement of circuits for induction heating.

tions to the induction coil or to the condenser plates. This energy is used very rapidly and it is necessary to supply continuous power if the oscillations are to be prevented from dying out.

There are several methods of producing the necessary oscillations, but modern thermionic valves provide the most efficient and convenient method, and in heatronic practice valve oscillators are employed. These oscillators are simple and remarkably reliable and can be made to give outputs varying from fractions of a watt up to thousands of kilowatts. There are three main components in a valve oscillator system, viz.:—

(a) A rectifier.
(b) A primary circuit and generator.
(c) A secondary circuit.

The rectified input to the primary or generating circuit is partly dissipated by the valve anodes and partly led to the primary oscillating circuit. Energy from the primary circuit is transferred to the secondary circuit, the amount depending upon the method of coupling between the two circuits. In practice there is always a loss of energy in this transfer. Fig. 6 illustrates diagrammatically the arrangement of the circuit.

In the induction method of heating, the material is placed within a coil supplied from the secondary circuit, and in the capacity method the supply is led to condenser plates. This arrangement is shown in Fig. 6. In practice, the condenser plates are attached to the plates of a press or to some other clamping device. The metal condenser plates have to be suitably insulated from the body of the press, and a diagrammatic arrangement is shown in Fig. 7. In addition, a further practical point which has to be taken into account is that the whole apparatus has to be suitably screened in accordance with Post Office regulations, since the HF energy would seriously interfere with radio reception in the vicinity. The necessary screening of the apparatus does not involve a great deal of trouble or expense, a double layer of ordinary narrow-mesh wire netting being adequate for the purpose. Full details can be obtained from the G.P.O., who also issue the necessary permit to use such apparatus.

There are several methods of arranging the material between the condenser plates or electrodes, and, indeed, of arranging the electrodes themselves. When considering the problem of cementing together a number of blocks of wood, for example, the pack of blocks can be arranged so that the glue lines are parallel with, or perpendicular to, the electrostatic

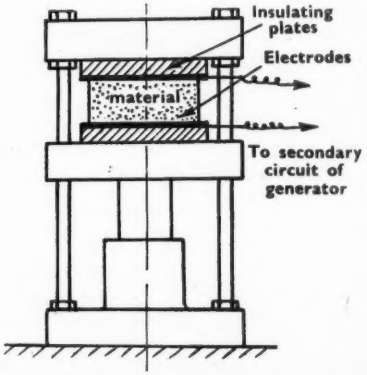


Fig. 7.—Arrangement of press for heatronic heating.

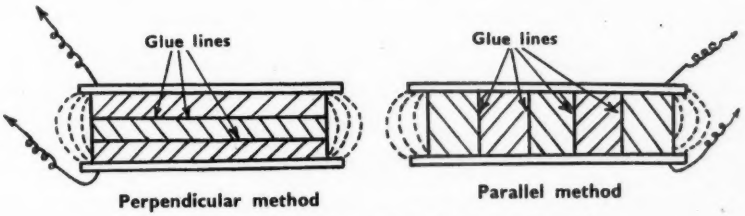


Fig. 8.—Different arrangement of work between electrodes.

field. (See Fig. 8.) Another method exists which is known as the "stray field" method, and is used principally when it is desired to join together two sections where it is difficult or impossible to place the work between two parallel electrodes. An arrangement of "stray field" heating is shown in Fig. 9.

The perpendicular method is used largely in the manufacture of plywood, forming curved laminated sections and for pre-heating plastics prior to pressing. The parallel method is more efficient, since the greater part of the power will be absorbed by the glue lines rather than by the wood itself. It is possible in some cases to use smaller generators if the parallel method is adopted. The "stray field" method presents the greatest practical difficulties, but, in some cases, is the only method which can be utilized. In this method, advantage is taken of the electrostatic field between two electrodes —which usually take the form of tubes or rods. The field as it fans out from one electrode and converges towards the other is made to pass through the glue line.

A further arrangement for the electrodes, a variation of the parallel or perpendicular methods, is shown in Fig. 10. Here a third electrode is introduced between the two which are attached to the press. These latter electrodes are interconnected, and are commonly fed from the valve oscillator. The advantage of this method is that two stacks can be cured at the same time, thus further increasing the productive capacity of the press.

Another aspect of the heatronic method of heating which it is important to bear in mind is that of safety precautions to eliminate the danger of operators being burned. There are several methods which can be satisfactorily adopted. Steinway and Sons, of America, who are using high-frequency heating for the manufacture of numerous aircraft parts, make use of the fact that a bulb, when in the proximity of energized electrodes, will light. Their operators wear bulbs on their overalls so that when approaching dangerous portions of the apparatus they have visible warning. Similar bulbs are fixed to the machines so that the operators know that if the warning bulbs are alight the machines are energized. The same concern uses guard gates around the apparatus the opening of which automatically shuts off the current. The fitting of automatic time switches will also provide an additional safety measure.

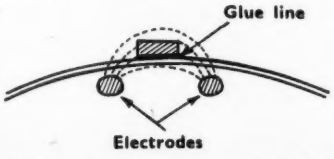


Fig. 9.—Arrangement for "stray field" heating.

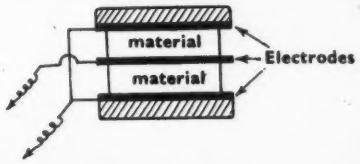


Fig. 10.—Additional arrangement using third electrode.

Basic Formulæ

When using the heatronic method of heating there are certain basic formulæ which can be employed to determine the quantity of heat and power which will be required to raise any given volume of material through a given temperature range. The time necessary for heating can also be determined.

The quantity of heat required to raise a mass of material through a given temperature range is shown by the expression:—

$$Q = WE\ (T - t) \quad \text{.....(1)}$$

where Q = quantity of heat required (B.Th.U.s)
w = weight of material (lb.)
T = max. temperatures required (°C.)
t = initial temp. of material (°C.)
e = specific heat.

In connection with the above expression it must be appreciated that the specific heat varies with the moisture content. This applies particularly in the case of wood veneer materials. Because of this it is necessary to obtain the true specific heat for a known moisture content, and to use the corrected value in the expression for quantity of heat required. The true value of specific heat can be obtained from:—

$$E_1 = \frac{(m + 32.4)}{(m + 100)} \quad \text{.....(2)}$$

where E_1 = specific heat (corrected)
m = moisture content (%).

Having determined the amount of heat required it is now necessary to find out the heat which is available from a given input of electrical power. Since 1 kw. is equivalent to 3,413 B.Th.U.s-hr., the heat equivalent of a given power input can be computed from:—

$$Q_1 = \frac{3,413.P}{60}$$

and if it is assumed that 50 per cent. of the power input to the generator is transmitted to the material, and that 10 per cent. of this heat is lost to the press and atmosphere, the expression then becomes

$$Q_1 = \frac{3,413\ P \times .50 \times 1.10}{60}$$

$$= 31.286 \times P \quad \text{.....(3)}$$

where Q_1 = heat equivalent (B.Th.U.s/min.)
P = power supplied (kilowatts).

By transposition this equation may be used to determine the size of generator required for a given job if the quantity of heat necessary is known (as obtained from equation (1)).

Having now obtained the heat required and the heat equivalent of the electrical power supplied, it is possible to determine the length of time for which the power must be applied. This is given by the expression

$$M = \frac{Q}{Q_1} \quad \text{.....(4)}$$

where M = time (mins.)
Q = heat required to heat material (B.Th.U.s)
Q_1 = heat equivalent of power supplied (B.Th.U.s/min.)

In order to find the electrical power converted to heat in terms of electrical quantities, the following expressions are employed:—

$$P = \frac{VA \cos \phi}{1,000} \quad \text{.....(5)}$$

where P = power (kilowatts)
V = volts
A = amperes
$\cos \phi$ = power factor

but $A = \frac{V}{Z}$

where Z = impedance
and for a capacitance

$$Z = \frac{1}{2\pi fC}$$

where f = frequency (cycles/second)
C = capacitance (farods).

Substituting in equation (5)

$$P = \frac{2\pi fC\ V^2 \cos \phi}{1,000} \quad \text{.....(6).}$$

By using the formula for a plate condenser equation (6) can be developed further to express the power in terms of

the dielectric constant of the material and its physical dimensions, thus:—

$$P = \frac{1.57\ fKF^2 \cos \phi}{10^{11}} \quad \ldots\ldots\ldots\ldots (7)$$

where K = dielectric constant

F = field strength (volts/cm.).

The effect of moisture content has already been mentioned in connection with its effect on the specific heat of a material. Variations in moisture content also affect the true value of the dielectric constant and the power factor, both these quantities increasing with the moisture in the material. This fact should be borne in mind when using equation (7) above. Concentrations of moisture within the material may also result in local hot spots causing uneven heating and distortion.

Some Applications of Heatronic Heating

Having dealt at some length with the theoretical aspects of heatronic heating, it is now proposed to describe briefly some of the applications to which this method has been successfully applied in the plastics field. This will be done under three main headings, viz.:—

(1) Laminated wood products.

(2) Pre-heating of moulding powders.

(3) Welding of thermoplastics.

(1) Laminated Wood Products

The use of high-frequency heating for the manufacture of plywood has been largely developed in America, and in many plants its adoption has resulted in very appreciable increases in output. Steinway and Sons, of America, installed their first high-frequency apparatus in 1941 for gluing-up piano frames, and the results were so successful that the plant has been extended, and this method is now utilized in the manufacture of wooden glider units and assemblies. A few notes regarding the experience of this concern will be given as being of general interest.

A glider wing bow measuring $1\frac{1}{16}$ ins. by 13 ins. by 16 ft. 9 ins. long was one of the first components to be treated by high frequency. Formerly this part required a curing time of 4 hours under pressure. The laminations were cemented together with a urea-formaldehyde glue, and the whole bow weighed 57 lb. After the press was adapted to heatronic heating, the curing time was reduced to $8\frac{1}{2}$ mins. In addition, the amount of spring-back in the bow after removal from the press was reduced by 75 per cent. as compared with cold setting in the press.

Steinways have found it an advantage if the electrodes overlap the edges of the work by an amount approximately equal to the distance between them. Excess glue squeezed out from between the laminations tends to cause flash-over, but this can be prevented by swabbing away the glue with cotton waste. If a mechanical spreader is employed, uniform moisture distribution can be obtained ensuring uniform heating, and, in addition, the danger of flash-over is practically eliminated. Another satisfactory method of safeguarding against flash-over is to insert a non-conductor between the work and the electrodes, thus preventing excess glue coming into contact with the electrodes.

Burning of the material will result if any metal parts are present. Nails for holding the various pieces together in the press are commonly found, and if these lie in a plane at right-angles to the electrodes, that is, parallel with the field, the voltage drop along them will cause them to heat to such an extent that charring and burning of the wood may result. If the metal parts lie parallel with the electrodes there will be no danger of burning.

If presses are properly located one high-frequency machine can be kept in continuous operation. It has been found that by keeping the size of the presses within 50 per cent. of each other it is not necessary to adjust the tuning of the output circuit.

(2) Pre-heating of Moulding Powders

The use of heatronics for pre-heating moulding powders has been discussed in some detail by Dring in a paper read before the Institute of the Plastics Industry and abstracted in the January issue of this journal. It is not, therefore, proposed to go into any great detail in the

present article, but the major advantages will be recapitulated.

In this application the moulding powder can be either placed in a suitable porcelain or other inert container, and the whole placed between the condenser plates, or, alternatively, pre-forms can be placed within the condenser field. Heating of the material proceeds rapidly and uniformly, until polymerization has commenced. The material is then quickly transferred to the mould.

With such pre-heating, it will be appreciated that the length of time in the mould can be considerably reduced since the question of heat transfer from the mould to the centre of the material does not assume important proportions. To quote an example, the curing time for a moulding half an inch in thickness, using the conventional method of heating, was found to be approximately 3½ mins. When heatronic pre-heating was employed this time was reduced to a little over half a minute.

In addition, the " flowability " of the plastic is increased, resulting in a more homogeneous structure of the moulding. Lower pressure can also be employed without danger of voids.

(3) Welding of Thermoplastics

A comparatively recent application of high-frequency heating in the plastics field is for the welding of thermoplastic materials. The joining of thermoplastics by means of solvent adhesives was in many ways unsatisfactory.

For this reason investigations were started with a view to establishing a method of welding plastic materials. Two methods of doing this were eventually evolved, the first utilizing a hot-air torch and the second using high-frequency electricity. It is with the latter method it is proposed to outline in this article.

The same theories regarding the capacity current method of heatronic heating apply. The material to be welded is placed between electrodes supplied from a suitable valve oscillator. Two types of welding come under this main heading, viz., stationary welds and continuous welds. In the first category are butt welds, lap welds, spot welds and " T " welds, whilst the second covers long seam welds carried out continuously on suitably designed machines.

The whole question of using heatronics for welding has been dealt with by Zade in a recent article in this journal. He points out that the heating effect obtained is dependent upon the square of the field strength (refer to equation 7 in this article), and describes briefly a method of plotting the field by the use of an electrostatic bridge. Much of the success of the welding operation depends upon the size, shape and location of electrodes.

Welding thermoplastics by means of heatronics has not yet been fully developed, but there does seem to be numerous applications when its adoption would prove to be beneficial.

Before leaving the subject, a little more detail of the continuous method may be of interest. When it is desired to make a long seam weld the two sheets of material are first spot-welded on a machine resembling the type used for metals, but whose electrodes are connected to the HF generator. For making the seam weld a machine is used having two roller electrodes, one driven and one spring loaded. The seam is fed between the rollers and the speed of the driving electrode controlled to give time for the material to become plastic. Bonding occurs under pressure from the second electrode and the material cools as it leaves the rollers.

General Remarks

Although the economies which can be effected in time, man-power, plant and space are very considerable, heatronics should not be regarded as an answer to every problem. For example, the value of their adoption for producing thin sections of plywood or laminated plastics is debatable owing to the danger of flash-over between the electrodes, and the fact that on thin sections the curing cycle with conventional steam or electrically heated platens is comparatively small. For thick sections, however, there can be no doubt as to this value.

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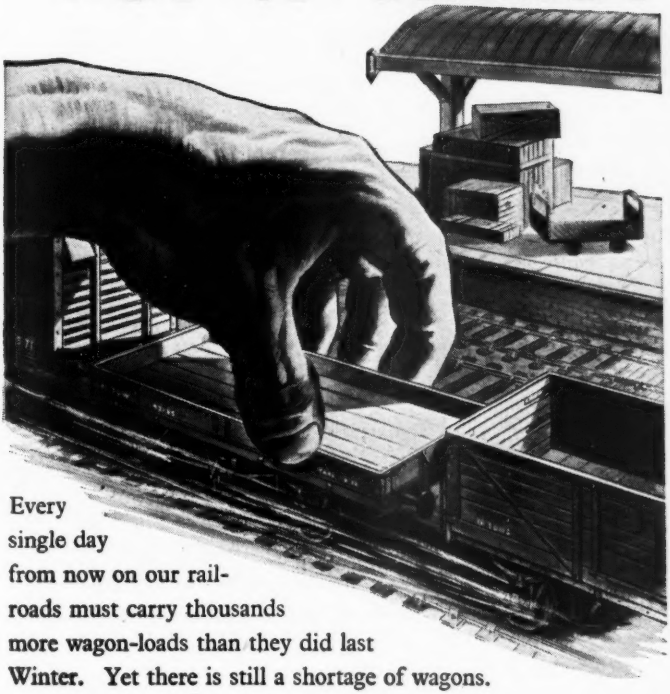

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Behaviour of Plastics at Elevated Temperature

This summary (after Frey, in "Schweizer Archiv," 1944/10/39) deals with the effect of temperature on the behaviour of plastics subjected simultaneously to mechanical stressing. Difference between laboratory data in this regard and reactions in actual service is emphasized

WITH the increasing application of organic structural materials to a wide variety of machinery and apparatus and, more especially, where these materials are being employed for stressed components, it is essential that the constructor be in possession of reliable and complete data regarding the mechanical properties of the material he intends to employ.

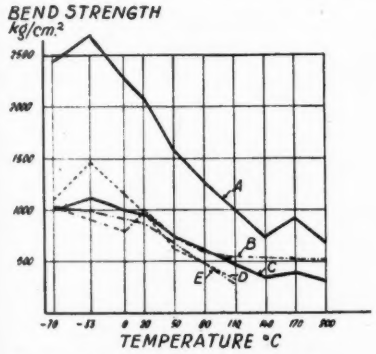

Fig. 1.—Bend strengths as function of temperature: A, impregnated paper (HPOPb); B, thermoplastic with asbestos-fibre fillers; C, thermoplastic-type, HPOP; D, urea resin HCOP; E, polystyrene.

Technical literature has already made great strides in the provision of this very necessary information and, in the form of tabular summaries, has presented the results of numerous relevant researches. When applying the figures so obtained, however, to practical ends, it must always be borne in mind that such data are the results of determinations carried out under specific conditions, for example, at a given temperature or at a given rate of loading. If, in actual service (as is more than likely to be the case), conditions of loading depart widely from those set out in laboratory reports, then the question may well be asked as to how far, if at all, variations are to be expected in the properties manifested. In other words, to what extent may the tabular data be relied upon? The following observations are made from the practical standpoint, more especially with respect to the strength properties in the heated state and with respect to the dimensional stability at high temperatures. This last is of importance, for apart from what will commonly prove a temporary deterioration of strength as a result of exposure to high temperature there will appear under conditions of service loading deformation. If, furthermore, the material has appreciably softened as a result of heating, then this change of form

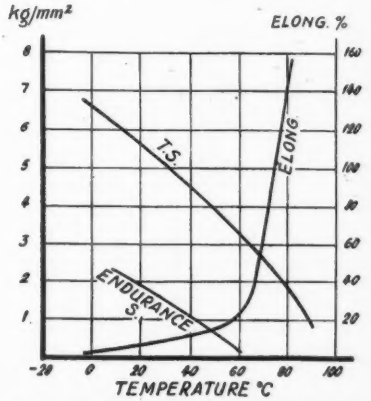

Fig. 2.—Mechanical properties of polyvinyl chloride as function of temperature.

will have occurred within the plastic range and its effects will be permanent.

It is characteristic of by far the larger class of plastics that the changes referred to begin to take place well within normal temperature ranges, hence their effects have always to be reckoned with right from the commencement of the creation of a design in plastics, that is from the drawing-board stage upwards. The degree to which such changes occur will vary widely between the thermosetting and thermosoftening plastics and, to a

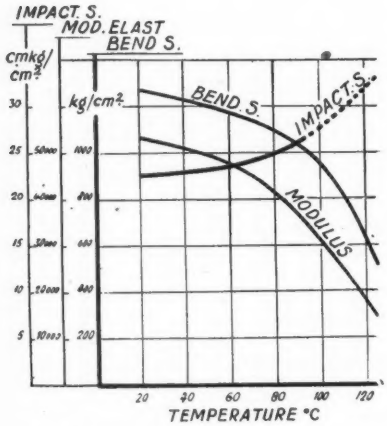

Fig. 3.—Mechanical properties of aniline-formaldehyde paper laminate as function of temperature.

lesser extent, between each member of each of these two main groups.

Although the observations to be made apply principally to mechanical properties, it should be pointed out that, to a lesser extent, analogous changes occur in electrical properties, a fact to be attributed to the increased mobility of the electrically asymmetric molecules characteristic of the materials.

Stress-Strain Diagram for Plastics

In order to be able to visualize the effect of temperature and time on the stress-strain diagrams typical of plastics, it will be convenient, first, to indicate the most important results by referring to certain experimental curves. In this way the relationship between the effect of temperature on mechanical properties can then be correlated with chemical structure.

As shown in Fig. 1, the effect of heating is, in general, to produce, with gradually increasing temperature, a marked decrease in strength (in this instance, bend strength). This fact also holds good for impact strength. It has been shown by Nitsche and Salewski to apply to most of the many classes of synthetic resins; thus it is true not only of thermosoftening plastics, for example, polystyrene, but also of the thermosetting phenolics and urea resins. To a large extent it is independent of the filler used.

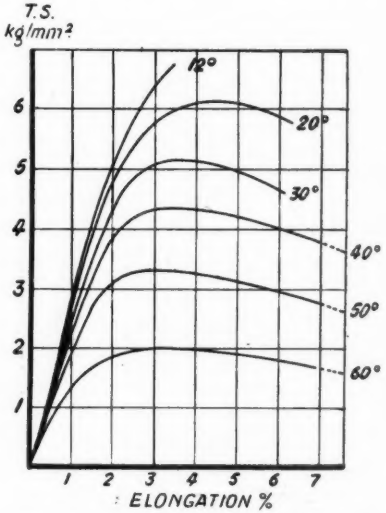

Fig. 4.—Influence of temperature on elongation of plastics for extension rate of 1.25 mm. per minute.

As might be expected, if attention be given to pliability and extensibility, then these properties also, above a certain temperature range, show marked increase, as illustrated in Fig. 2 for polyvinyl-chloride The modulus of elasticity,

(Continued on page 231)

A New Process for Making Moulds by Electrodeposition*

By P. SPIRO, B.Sc., A.C.G.I.
(London and Scandinavian Metallurgical Co., Ltd.)

IT is well to know that the ordinary tool-room is one of the bottlenecks in the plastic moulding and die-casting industries. Moreover, the cost of moulds and dies, especially in the case of intricate shapes is very often a decisive factor in the manufacture of the finished product. Any saving of cost or time in the production of such moulds is, therefore, of considerable interest.

The process under review is designed to overcome the costly machining of such moulds in cast iron or alloy steel, making it possible to dispense with the highly skilled labour employed in their manufacture heretofore. It consists essentially of producing an electro from a reproduction of the job to be moulded and of backing this up with cast or sprayed steel in a cast-iron or steel frame.

The master of the job to be manufactured is made in easily machinable plastic. Incorporated in this pattern are also, for instance, as in the case of compression moulding, the surface of the loading chamber and accommodation for ejector and core pins. Such modifications might be required for compression moulding, injection moulding, or pressure die casting, and further additions envisaged in the case of gravity die casting might be the incorporation of runners, risers and extensions facilitating venting.

This master is well polished and given a metallic conductive coating of negligible thickness. A nickel alloy is then deposited on to it by a special process, giving a tough shell roughly an eighth of an inch thick with a stable Brinell hardness of 400 to 500.

The plastic master is now removed, leaving a die with dimensions correct to a fraction of a thousandth of an inch, with a mirror finish equal to that so easily obtained on the master. This method, therefore, not only obviates the machining of cast iron or alloy steel mentioned previously, but also produces a mould of sufficient hardness without resorting to heat treatment.

The master is usually so constructed as to produce on the nickel-alloy shell a flange of a simple geometrical shape coplaner with the flash line or the upper rim of the loading chamber. The shell is

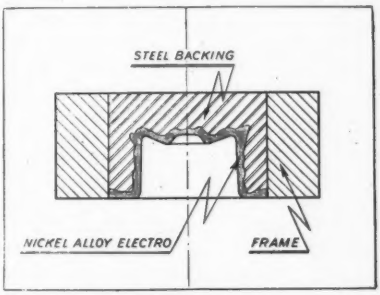

Fig. 1.—How the mould is built up on the alloy shell.

then fitted by means of this flange into a frame or bolster of case-hardened mild steel, or, in the case of gravity die castings, of cast iron. Vacant spaces at the rear of the shell are then filled up with steel by the method outlined in British Patent No. 550,563, which is the patent covering the tool-making process forming the subject of this article and being, in content, if not in form, almost identical with it.

A cross-section of the resulting die block

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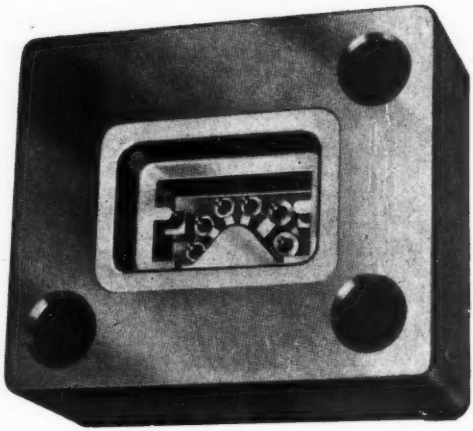


Fig. 2.—Mould built up from electrolytically deposited nickel-alloy shell.

is shown in Fig. 1, indicating the different materials used, while the photograph, Fig. 2, illustrates the lower force of a mould manufactured by this process, and Fig. 3 a moulding produced from it.

The advantages of this process over orthodox die-sinking methods lie in its economy and short delivery period. It is obvious from the foregoing that during the electro-forming period, which takes about a week, the tool "forms itself," at practically negligible labour or other cost. Another economic advantage is the ease with which a positive master can be shaped from a soft plastic by milling and turning, there being no limit to the depth of the cut, as there would be in ordinary die sinking. The labour cost of this stage amounts to 25 per cent. of that involved in ordinary die-sinking methods and is still less for complicated shapes, which can be built up from simple parts, using a suitable plastic, whilst any part inadvertently machined "under" can be built up again, using the plastic in its liquid form.

Artistic and fancy shapes can be hand carved and figures engraved easily on the master, resulting in embossed characters on the mould surface. Under present conditions, the process has a wide scope in the production of the complicated parts associated especially with the aircraft industry. During the present emergency this economy in skilled tool making, high-grade machine tools and alloy steel obviously commends itself.

A further advantage of the nickel-faced dies is that they are more resistant to tarnishing or chemical attack by the plastic or the metal being formed.

An associate member of the Institution of Production Engineers, whose firm had the opportunity of testing and inspecting dies and moulds made by the new process, recently expressed the opinion, formed after overcoming considerable initial scepticism, that these tools would give satisfaction in the pressure die casting of tin and zinc alloys and in injection moulding, in which fields they have

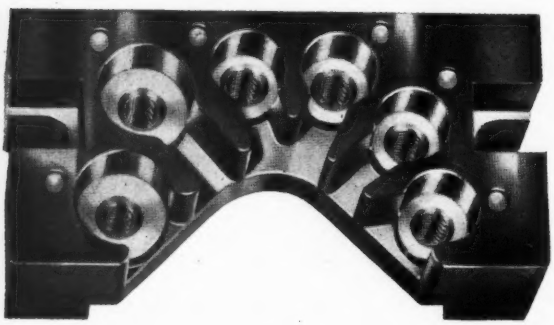


Fig. 3.—Typical moulding produced from the die shown in Fig. 2.

been extensively tested. This should also apply to aluminium die-casting, but as yet only initial work has been done in this direction.

With regard to compression moulding, the opinion expressed was that it was as yet too early to say whether such a tool can replace an alloy steel mould for very long runs, but, nevertheless, the scope in the plastics field for the new type of mould can be very large, and, furthermore, by reducing the initial cost, the process is likely to enlarge the general scope of compression and other plastic moulding. It might also lead to greater freedom of design owing to ability to break away from the usual geometrical shapes.

In the case of gravity die-casting economic and delivery advantages are not so pronounced as cast-iron dies are normally used, which are easier to produce than a heat-treated alloy steel mould. Here, however, the new process shows prospects of important technical advantages. Results achieved up to date suggest the possibility of obtaining castings with a previously unknown fineness of surface finish. This can be achieved by using the new type of mould without wash.

Incidentally, the unwashed mould has a chilling effect on the casting, giving a finer grain size and consequent higher tensile strength.

Further applications envisaged are the use of moulds made by this method as masters for the manufacture of moulds by the Keller machine or as moulds in which such masters or other castings can be made, as, for instance, from a phenolic cast resin, the lead moulds now used for this process being often found unsatisfactory.

BEHAVIOUR OF PLASTICS

(Contd. from p. 228.)

conversely, decreases strongly, as shown in Fig. 3, with respect to Cibanite resin.

Experience has also demonstrated that, with increase in temperature, deterioration in strength properties is accompanied by softening of the material. This loss in hardness does not occur suddenly, but takes place progressively over a wide temperature range, as shown in Fig. 4.

To attain the required degree of extension at a given rate of deformation, the load to be applied decreases with increasing temperature; this is quite obvious, as the material softens appreciably when heated and becomes more plastic. The process of softening itself also gives rise to the fact that the velocity of extension itself can exert a marked effect on the final result. If the process of extension be very rapid, then the achievement of any given degree to elongation requires a greater loading than with slow elongation. The reason for this is to be attributed to flow which occurs during the plastic deformation of the softened material. The flow process tends towards a balancing out of any applied load. In fact, in general, the behaviour of the material under these conditions is that of a viscous fluid.

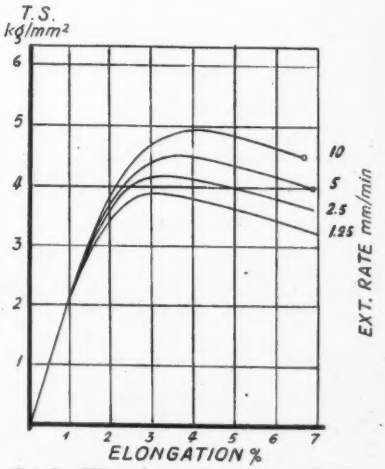


Fig. 5.—Effect of rate extension on elongation of polymethyl-methacrylate resin.

(To be continued).

Lacquered Aluminium Wire

Presenting a Summary of Investigation by Greulich on the Embrittlement of Lacquer Coatings on Aluminium Conductors

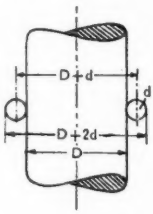
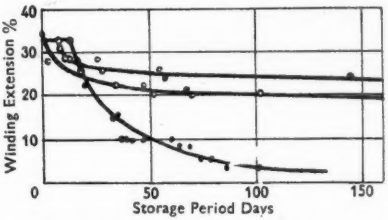


Fig. 1 (left).—A diagrammatic representation of scheme for determination of bending strain of lacquered wires.

Fig. 2 (below).—Curves showing influence of storage at room temperature on winding elongation of lacquered wires.
Blacked-in circle—oil-lacquered wire 0.9 mm. dia.; open circle—phenolic-resin-lacquered wire 0.9 mm. dia.; half-blacked-in circle—phenolic-resin-lacquered wire 1.1 mm. dia.



THE production of lacquered aluminium wires has often led to difficulties due to the adhesion of the lacquer becoming reduced during storing, with the result that, after a short time, the wires could no longer be worked.

This phenomenon is generally considered to be due to the fact that the lacquer layer becomes brittle through absorption of oxygen, a condition favoured by the thin oxide film always present on the surface of the metal. An attempt was made to improve adhesion by pre-treatment of the wire, for instance by pickling or provision of films which give a good anchorage for the lacquer. Such a treatment is expensive and increases the price of the wire.

If this presumption be correct, an improvement could be expected with oil-free phenolic-resin lacquers, which do not absorb oxygen during storing. In order to investigate this problem, E. Greulich,* of the Research Laboratory of the Isolation A.G., Mannheim, carried out tests with 20-gauge and 18-gauge wires. The oil lacquer contained 37 per cent. oil, the phenolic-resin lacquer being free from oil. A combination treatment was also examined using three undercoats of phenolic resin lacquer and three finishing coats of oil lacquer.

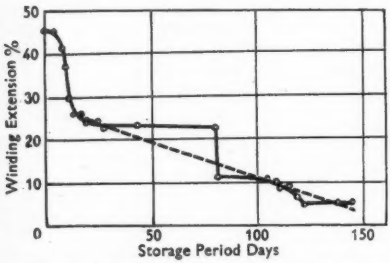


Fig. 3.—Influence of storage at room temperature on winding elongation of wires treated by combined coating with oil lacquer and phenolic-resin lacquer.

Difficulties in treatment of aged lacquered wires are caused by lack of flexi-

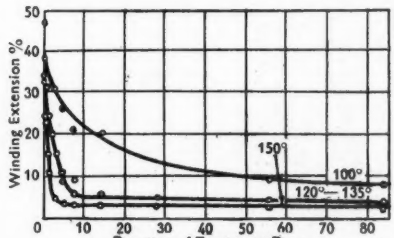


Fig. 4.—Influence at temperatures between 100 deg. C. and 150 deg. C. on the winding elongation of an oil-lacquered aluminium wire 0.9 mm. dia.

* Elektrotechn. Zeitschrift, 1943/64/241.

bility. As the lacquer layer breaks off when winding on spools, this operation may be utilized as a test for brittleness. The influence of wire diameter should be excluded, in order to transfer the results obtained from one wire diameter to the other, by calculating the strain arising in the extreme fibre during winding.

Fig. 1 shows a core of diameter D, around which the wire sample of diameter d is wound. During winding, the lacquer film near the core is compressed and the outer fibre stressed in tension; the central fibre is obviously neutral. The strain of the outer fibre is given by the difference in diameter between the diameter of the outer layer and the diameter of the neutral fibre, thus

$$E = (D + 2d) - (D + d)$$

The extension of the outer layer is, therefore, equal to the wire diameter. This extension effects different lengths of the wire, according to the spool-core diameter applied; thus the extension has to be referred to the length of the neutral fibre being equal to (D + d), whence the reduced extension becomes:—

$$E_r\% = \frac{d}{D + d} .100$$

This relation permits the calculation of the extension independently of wire and spool core diameter.

The research was undertaken in such a way that, after finishing the lacquered cable, winding samples were taken every two days, spool core diameter being varied in such a way that crack formation was caused between two closely adjacent turns. It was observed, for instance, that, after two days' storage, cracks occurred with a 0.9 mm. wire when using a 2.25 mm. core, but not in the case of a 2.5 mm. core. Thus, in the case of the 2.25 mm. core, maximum layer tension is clearly reached.

For investigating the influence of heat, the wires were exposed to temperatures of 100 degrees C., 120 degrees C., 135 degrees C., and 150 degrees C. for periods from half an hour to three months in dry ovens. After storage, a winding test was performed on the sample at room temperature.

The ageing of oil-lacquered wire starts after 12 days, and capacity for winding is considerably reduced. After one month the elongation is only 10 per cent. of the original value, and, after 100 days the very low value of 3.5 per cent. is reached, corresponding to a spool core of 28 times the wire diameter.

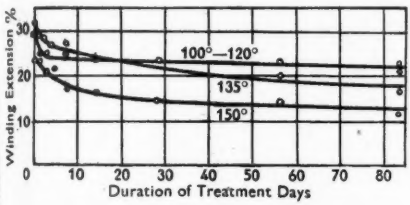
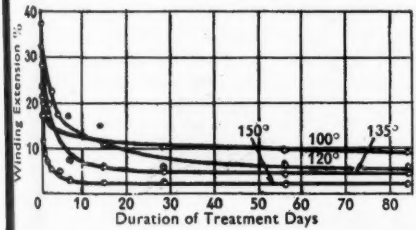
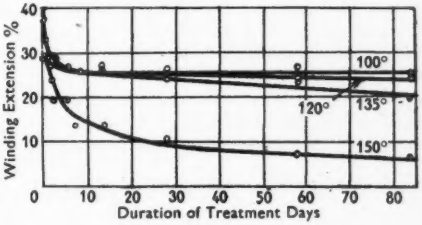


Fig. 5 (above).—Influence of temperatures between 100 deg. C. and 150 deg. C. on the winding elongation of a phenolic-resin-lacquered aluminium wire 0.9 mm. dia.

Fig. 6 (right).—Influence of temperatures between 100 deg. C. and 150 deg. C. on the winding elongation of a phenolic-resin-lacquered aluminium wire 1.1 mm. dia.

Fig. 7 (below).—Influence of temperatures between 100 deg. C. and 150 deg. C. on the winding elongation of an aluminium wire 0.9 mm. dia. treated with combination coatings of oil lacquer and phenolic-resin lacquer.





In contrast to the oil-lacquered wires, phenolic-resin-coated wires, after 150 days, give extension values of 20 to 24 per cent., corresponding to spool-core diameters of four times the wire diameter. The capacity for storing is, apparently, not limited for these wires.

The behaviour of the wires treated with both lacquers seems to be between that of the oil and phenolic-resin-treated cable (Fig. 3). During the first fortnight, extension is reduced from 45 per cent. to 28 per cent. and remains at a value of 22.5 per cent. for up to 80 days. It then drops during the next two days to 10.8 per cent. and the process of embrittlement continues for 110 days. Thus a stepwise course is obtained, which could partly be observed with the oil-lacquered wire (Fig. 2). As 23 per cent. extension is not sufficient for storage up to 80 days, the manufacture of such composite-treated wires is of no value.

Continual preheating to 100 degrees C. makes the oil-lacquer film very brittle (Fig. 4). The reduced extension drops after a treatment of 56 days to 9 per cent.; thus the wire cannot stand great bending stresses. At temperatures of 120 degrees C. and 135 degrees C., the brittleness, after 10 days' treatment, has already progressed so far that the wire has become useless.

Phenolic-resin-lacquered wires show highest resistance to heat (Figs. 5 and 6). Temperatures up to 120 degrees C. are without influence, as reduction in extension remains within the limits of ageing at room temperature. At a temperature of 135 degrees C. and after 50 to 60 days, the first sign of increased brittleness is observable. This is, however, so small that there is no objection in using these wires up to this temperature. Still more pronounced brittleness begins at about 150 degrees C. and the extension of the lacquer film sinks, after a fortnight's continual heating, to a value of 15 per cent.; this figure may represent the limit for practical use; the wires, therefore, can be subjected to casual heatings up to 150 degrees C. (302 degrees F.) without suffering great damage.

Combination-lacquered wires withstand continual heating less well than pure oil-lacquered cables. Even at 100 degrees C. the brittleness is very marked and occurs after a short period (Fig. 7). This, again shows that there is no purpose in producing these cables.

The result is that oil-lacquered wires become rapidly brittle and do not give satisfactory cables. Oil-free phenolic-resin lacquers show only a slight drop in extension at room temperature.

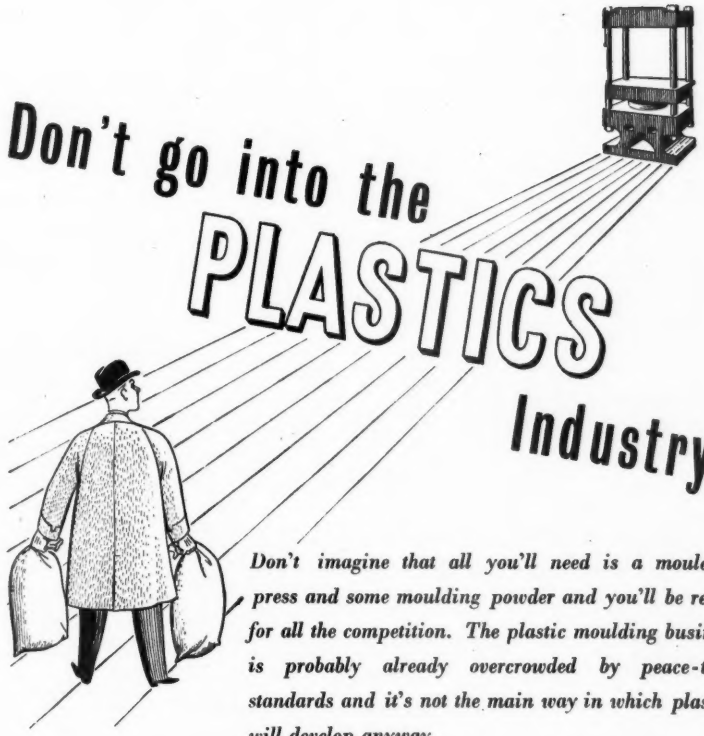
Storing quality can be considered as guaranteed for six months, and the wires can stand up to temperatures of 135 degrees C. or, for short periods, even up to 150 degrees C. The suitability of phenolic-resin lacquer is therefore confirmed and the problem of the manufacture of satisfactory lacquered aluminium wires can be considered as solved.

Plastics in Road Vehicles

At a recent combined meeting of the Institute of the Plastics Industry and the Institute of Automobile Engineers, Dr. Sisson, of I.C.I. (Plastics), Ltd., gave an interesting talk on the above subject, in which he set forth some of the controversial points in the problem. The cost of tools and time of curing of thermosetting resins were discussed, but disadvantages in these respects, especially the latter, may yet be overcome. The thermoplastic materials came in for special mention with reference to the fabrication of " show " or experimental models, shaped lights, etc. It was interesting to hear, too, that polyvinyl chloride showed promise for use as window fillets instead of moulded phenolics, which had often failed through breakage. It may be pointed out, too, that the cheap moulded fillet, which failed even in transport to the motorcar works, was forced on the industry by certain car manufacturers. Superior moulded fillets made from thermosetting resin would not necessarily fail.

One speaker in the discussion appeared to have a grudge against the soya bean as a filler for plastics.

Don't go into the PLASTICS Industry



Don't imagine that all you'll need is a moulding press and some moulding powder and you'll be ready for all the competition. The plastic moulding business is probably already overcrowded by peace-time standards and it's not the main way in which plastics will develop anyway.

You're probably in the plastics business already and don't know it. Don't you already have to bind things together? Don't you make something that could be stronger, lighter or more weatherproof? Are you in paint, timber, textiles, paper or a hundred and one other trades?

The possibilities of BEETLE RESINS (Urea-Formaldehyde thermo-setting plastics) used as a binder with other material are well-nigh unlimited—that way lies the greatest post-war use of plastics and there's probably a use for this type of plastic development right on your own doorstep.

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PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

PLASTICS AND CHEMICALS FROM HYDRO ELECTRICITY.—The vast possibilities being opened up by the projected "Power for the Highlands" hydro-electricity scheme were discussed at the recent Association of Scientific Workers meeting held in Edinburgh. Mr. George Muir, of Glasgow, said that the schemes created great possibilities for the Scottish people in general and for those engaged in the industries in particular. The raw material resources of the Highlands which could be developed when the power was available included the enormous dolomite resources of the Durness area and the rich limestone reserves in the Fort William area. The possibility of setting up a magnesium industry in the Lairg to Dingwall area and a carbide industry to the north of Fort William were thus envisaged.

The growing importance of plastics and synthetic rubber based on the carbide industry made it extremely important that Scotland should develop the carbide industry. If she was to get the fullest advantage from this development it must also be seen that the plastics and synthetic rubbers were also developed in the same area.

The same applied to the magnesium industry, which would be tied up with the light alloy industry, probably utilizing aluminium made in the Highlands. There was no end to the application of electricity to new light industries and to agriculture. But the fullest possible development must be made of all these opportunities if towns of adequate social size were to be created in the Highlands with proper facilities for education and cultural development.

The issued report of the hydro-electric scheme is an interesting footnote to this view. It shows that 102 sources and projects have been surveyed and tabulated for development with an estimated annual output of 6,240 million units per annum. Each project must be approved by Parliament, but it is hoped that actual work of construction will be started on certain selected projects which are far advanced, by the start of the autumn. In actual survey, the available output has been proved greater than was at first planned, showing that the fullest value of the available power sources had not, until this survey, been really appreciated.

MICANITE AND INSULATORS CO.—An interesting ceremony took place at the Empire Works, Walthamstow, of the Micanite and Insulators Co., Ltd., on Wednesday evening, April 5, when Major Stanley M. Mohr, managing director of the company, presented badges and cheques to nearly 100 members of the Long Service Association formed on February 18, 1943.

Major Mohr complimented Mr. W. J. Richardson, who was present at the meeting, upon having completed over 46 years' service with the company; Mr. C. Clayden, who had completed 44 years; and Miss Harriet Fletcher, more than 40 years.

Four others had been with the company for over 40 years and the total service of these seven employees amounted to 291 years.

Altogether, 64 members had service records of over 25 years, in recognition of which each was presented with a cheque for £25.

In addition, Major Mohr informed those present that henceforth all hourly paid employees who are members of the Association, i.e., over 20 years' unbroken service, would receive full pay during absence owing to illness for two weeks and a further two weeks on half pay. Also, hourly paid members of the Association would in the future receive an extra week's holiday with pay.

TELCON SAVINGS.—The Telegraph Construction and Maintenance Co., Ltd., informs us that the Telcon Works Saving Group raised the sum of £15,418 during "Salute the Soldier" Week. The closest forecast to this total was won by Mr. J. Peters, whose estimate was only 25s. out and who received five certificates as a prize.

INSTITUTE OF THE PLASTICS INDUSTRY.—The 12th annual general meeting of the Midlands Section was held at the Imperial Hotel, Birmingham, on Friday, April 28, 1944. Mr. A. H. Wilson (Messrs. Evered and Co., Ltd.) was

unanimously elected chairman for the ensuing session. Mr. C. P. Hughes (Bakelite, Ltd.) was unanimously re-elected honorary secretary for a further year.

The following were elected to serve on the committee for the ensuing session:—

A. R. A. Bettridge (Messrs. Ellison Insulations, Ltd.), C. Cleveley (E.M.B. Co., Ltd.), A. Hill (Messrs. Courtaulds, Ltd.), A. C. Hitchon (Bakelite, Ltd.), J. Hofton (British Industrial Plastics, Ltd.), L. C. Hudson (Messrs. J. Hudson and Co.), K. J. Mendl (British Industrial Plastics, Ltd.), R. Plant (Messrs. Cromwells, Ltd.), E. J. P. Reynolds (Messrs. Ellison Insulations, Ltd.), N. W. Sabin (Insulation Equipments, Ltd.), G. A. Street (I.C.I. (Plastics), Ltd.), S. L. Waters (Co-operative Wholesale Society), L. A. White (Bakelite, Ltd.).

Amongst the company present, 59 in all, was Mr. F. A. Cook, chairman of Council, and Mr. A. V. Percival, recently appointed secretary to the Executive Committee of the Plastics Industry for Educational Training.

MAJOR S. M. MOHR, who has been chairman of the British Plastics Federation for the past five years, retired from office at the recent annual meeting. This period, which embraces the most difficult of the war years, saw the rapid increase of membership of the Federation and the rise of raw material control, conditions which needed a strong guiding hand and tactful leadership. To mark their appreciation of his services, members of the Executive Committee of the Federation have presented Major Mohr with the gift of a silver salver. In making the presentation, Mr. H. W. Graesser - Thomas, the vice - chairman, referred to the retiring chairman's special attributes which enabled the enormous work done to be carried out expeditiously and to the reorganization of the Federation, which was due in so great a measure to his devotion to duty.

Major S. M. Mohr, O.B.E., M.C.

NEW BOOKLET

"Plastics in the Radio Industry," by E. G. Couzens and W. G. Wearmouth. Published by Hulton Press, Ltd. Pp. 57. Price 2s. 6d.

This little volume consists of a reprint of several articles written by the authors in "Electronic Engineering," and is a most useful introduction to the general subject.

It is simply and clearly compiled, describing the nature and types of plastics available, their manufacture and their moulding and fabrication. Of more practical interest to the radio industry is the chapter describing the various plastic products with their physical characteristics. There is a large number of excellent tables giving mechanical and electrical strength figures. We also like the inclusion of the paragraphs relating to molecular structure and electrical properties, etc.

LETTER TO THE EDITOR

Directors of Injection Moulders, Ltd.

The untimely death, in New York, last June, of my late partner and joint managing director, Mr. O. W. G. Doll, following as it did an absence of over three years on our company's business in the U.S.A., has led to a slight rearrangement of duties of our principal executives.

I have accepted appointment as chairman of the company, and, at my suggestion, Messrs. G. G. Ritchie and A. E. Davey have been elected joint managing directors. It is desired to place on record that their appointment marks our appreciation of the excellent services which they have rendered the company in these past difficult years.

A. GRAHAM DOWDING,
Injection Moulders, Ltd.
London, N.W.9.

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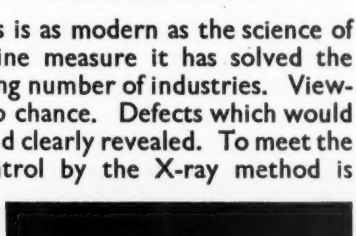

Radiograph of moulded assembly showing incorrect location of metal insert.

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Planned Mould Maintenance Service Aids Economical Production

By W. M. HALLIDAY

Being the first of a series of articles illustrating the desirability of, and the many advantages to be gained from, an intelligently organized method of mould maintenance.

The purposes of such method are not solely those of effectively covering actual repairs, or mould faults, but chiefly that of so arranging maintenance oversight in the form of regular inspection, checking, adjustment, replacement, and so on, that mould failures, etc., may be eliminated or greatly reduced in occurrence and seriousness.

IT would appear to be an obvious fact, and one which is certainly worthy of widespread appreciation amongst plastic moulders, that in order to achieve continuously successful production of moulded articles it is not sufficient only to expend skilled labour, time, and expense upon the provision of accurate moulds, without also providing for their maintenance in a comprehensive fashion so that they are kept in the best working condition throughout the length of their life.

In fact, it is safe to state that the maintenance service afforded to plastic moulds should form one of the most vital corner stones in any efficient moulding plant.

Every moulding manufacturer has to undertake some kind of mould maintenance, but experience of numerous organizations shows this usually to consist of a very irregular, infrequent inspection of moulds for the detection of developing faults, and generally attention is only given to a mould when some specific error, failure, or damage is encountered and the mould is no longer capable of being operated, or of producing parts to the requisite standards of accuracy or finish.

In addition the methods employed for storage of moulds not in productive use often leave much to be desired, whilst the means for accurately recording the extent and time of any repair work performed on a mould, or the analysis of repeated identical breakdowns, are often entirely neglected because of the lack of organization of this aspect of the moulding works activities.

Some Disadvantages Arising from Failure to Organize Maintenance

Unfortunately, such ill-planned practice results in much loss of valuable time on the part of skilled workmen and machines, and the writer can testify to the benefits to be gained by the expenditure of thought and attention to the problems of effective mould maintenance.

In order to spread greater understanding of the need for planning such activities on an intelligent, ordered basis, a listing of some of the main disadvantages which it has been noted accrue when this phase of moulding practice is not arranged systematically, is here presented. This no doubt will serve as a guide to those who hitherto have tended to neglect the subject.

(A) Where moulds are afforded no skilled and continuous maintenance attention, the speed of production will tend to decrease, owing to the more frequent stoppages to effect minor adjustments to mould and its various components. This will be especially noticeable in the case of moulds from which very long runs are required, as most moulds, however carefully constructed or designed, will begin to show distinct signs of wear, departure from initial conditions of smooth working and reliability, when they have produced a few hundred thousand articles.

(B) In regard to the finished moulded product, this will begin to depart from initial precision and surface finish quicker than normally to be expected, because of

the accumulated effects of wear, uncompensated adjustments, distortion of mould members, all of which individually may be of a very minor nature and seemingly unworthy of skilled corrective attention, but which combined and over a period will add up to more serious proportions in the shape of dimensional deviations in the finished article.

(C) The life of the mould itself may become very materially shortened, or its working efficiency impaired permanently, due often to the undetected presence of a small fault which, as time goes on, radically worsens until a major breakdown occurs and serious damage is caused. Thus there will be a consequent loss of investment imposed on the organization which will be reflected in moulder's profit account.

(D) Cases have been known where an order has been received for a very large quantity of mouldings, and before this has been completed the mould has been ruined as the result of some breakage or fault, which usually could have been foreseen by one skilled in the signs of developing faults at an early stage. In such instances another mould has to be made up in order to complete the remaining quantity of batch, and, of course, the moulding manufacturer is unable to pass this cost on to the client, and thereby he suffers additional loss, worry and delay.

(E) Numerous secondary operations to be performed on mouldings, such as drilling, tapping, dressing-off, flash removal, polishing, inspection and the like, may be very materially affected and increased in complexity, difficulty, extent or duration because of the failure to maintain the mould in the best possible working condition. Here again the moulding manufacturer will find himself confronted with additional costs which were not foreseen when estimates were made up.

(F) Costly and protracted corrective measures may also be found necessary in order to restore original accuracy of the produced article which has been lost because of unremedied wear or error in the mould. In this respect much time and expense can be absorbed as it is not always possible to scrap a quantity of mouldings even though that would be the cheapest way out. Delivery time is often the determining factor, so to satisfy the customer it may be essential to correct the faulty parts regardless of the extra cost.

(G) Setting-up time involved in fixing the mould on press or machine, and also testing operations are very often wasted because a mould may be drawn from the storage room, and set-up on the press only to find, when the first two or three samples are produced, that an error noticed during the previous period of use of the mould has not been corrected. The writer has known cases where a mould possessing some fault or other deleterious to proper production has lain in the storage room for a matter of months because someone had overlooked the need for attending to it at the time when the fault was noted. This sort of thing happens oftener than one would imagine in these days when most firms find their tool-making and production departments subjected to very great pressure.

(H) Yet another important disadvantage arising from an absence of planned oversight and maintenance, etc., is that the work pressure on the tool-room staff may be thrown considerably out of balance. Thus a number of moulds may be withdrawn from stores for production purposes at more or less the same time. Before production commences properly in respect of some of these moulds it is found that a number of items of maintenance have not received attention during their period of idleness. This results in a great rush of overhaul work on the tool room, which, of course, is immediately urgent. Thus other important work of mould manufacture may have to be put on one side, skilled workmen transferred from one task to that of repair, and things generally become disorganized. Such conditions, as every toolmaker knows, are the fruitful sources of errors, mistakes, oversights and faulty work.

In this connection it is not always sufficiently realized that die-sinking, engrav-

ing, layout, and other machining operations required in mould manufacture, are very highly skilled tasks and demand a considerable degree of concentration and uninterrupted attention. Such concentration will be marred if the operators are frequently interrupted in order to undertake rush repair work on faulty moulds

(I) In the matter of depreciation allotment, too, the works accountant may be very wide of the mark in making the customary nominal assessment, because a plastic mould may very rapidly deteriorate in a short space of time if continuously worked without skilled maintenance service. So a false monetary valuation of moulds may develop due to badly organized maintenance attention, and they will accordingly figure on the balance sheet with an inflated value as assets.

The Objects of Planned Maintenance

As will no doubt by this time have been gathered, the correct maintenance of plastic moulds, as viewed by the present writer, certainly involves much more than is comprised in the all-too-usual practice which embraces but a perfunctory examination of the mould upon its removal from the press after a production run has been completed. Such a cursory examination is often not even carried out by a skilled person conversant with mould construction. If the mould appears in "good condition" and apparently operates without trouble, it is given a somewhat hasty clean-up and then placed on one side there to await the receipt of the next repeat order.

In addition a suitable storage location is often not even provided, a feature which renders still more difficult the task of keeping effective check upon the condition of moulds not actually in use.

True maintenance necessarily involves a regular overseer service to cover repairs, replacement or broken or damaged mould parts, rectification, adjustment and neutralization of the effects of wear, modification to design, cleaning, etc.

But all these actions are chiefly, if not exclusively, concerned with the correction of some ascertained fault, after this has reached a certain stage of seriousness coinciding with interference with production or smooth working of the mould.

It should, however, be one of the prime objects behind any system of planned maintenance endeavours to secure the elimination of such faults, and not merely their correction.

Any plan should therefore be characterized by efforts combining regular inspection and tests of the mould to discover small deviations from sound condition, coupled with an intelligent anticipation or skilled foresight of developing troubles before these have had the chance to reach important dimensions likely to result in a mould failure.

Such a scheme of maintenance will also require some methods whereby all maintenance work, repairs, alterations and the like are carefully recorded and filed, so that a true apportionment of costs can be made, accurate information secured of the various maintenance activities surrounding a mould over a lengthy period, and also that responsibility for repair work performed on a mould may be more closely controlled.

Mould Design and Construction and Influence Upon Maintenance

It is an unquestioned truism to state that mould maintenance actually originates in the design department, where the features and constructional details and method of operation of a particular mould are created.

If a designer is able to give consideration and a little foresight to the probable working conditions to which a particular mould will be subjected, many minor snags of both construction and operation may be foreseen and forestalled by the provision of different or improved designs, or modifications in the construction of details and so on.

The good mould designer possessing wide and up-to-date workshop experience will have the ability to visualize the entire construction, methods of manufacture, and functioning even before transmitting

any of the design details to paper. Thus he will build up a purely mental provisional design outline picturing all the various component parts, their functions, movements in relation to one another, and broadly by what means they will be manufactured.

Another advantage to be gained by the designer possessing useful machining knowledge is that he will have a reasonably accurate idea of the extent of stresses, wear and pressures likely to be imposed on a part both during its manufacture as well as throughout its operation. Thus he will derive a good realization of the power required for the withdrawal of cores, that needed to operate ejector mechanisms, the effects of pressure, heat, or moisture upon the various materials composing the mould, and the durability of certain constructions to withstand wear, stresses, or excessive pressures and heat.

Equipped with this knowledge, the designer will thus be in a much better position to foresee many operating difficulties which might arise during the production stages, and accordingly be able to modify design features to secure maximum life and efficiency from the mould.

Much has previously been written on the subject of satisfactorily and economically relating mould design features with preferred moulding and operating requirements entailed in the plastic moulding process. Numerous illustrations have also been given demonstrating the manner in which various mould constructions have been selected, together with the practical advantages accruing. From such illustrations it will have been appreciated how important is the part played by the designer in creating mould constructions which ensure the minimum amount of maintenance attention as well as the maximum suitability in respect of finished moulded articles.

This aspect of designing practice and objects will be discussed at a later stage when illustrations will be presented to indicate some ways in which designs may be fashioned to afford the minimum maintenance service. Certain well-defined methods of construction have in practice been found more satisfactory from the maintenance angle and thus should be adopted wherever possible.

General Maintenance Factors

At the outset it will be advisable to deal with a number of factors which may be classed as general in that they are applicable to any class of mould and, in fact, are really matters of works organization or moulding and toolshop practice.

Testing.—The first factor to be mentioned is that affecting the methods of testing a new mould.

Very often a new mould may be returned to the toolroom for repair or overhaul as a result of being damaged or unduly strained during the initial testing stage before production has commenced.

Such damages have been found to be due to the operator or tool-setter not being fully acquainted or confident with the construction and methods of working the new mould. In the case of moulds of complex design or intricate construction, especially one having loose insertions, hand or mechanically withdrawn cores, difficult ejection mechanisms, and so on, it is highly essential that there be someone present throughout the testing operations who does completely understand all the mould details and points to ensure that it is mounted on machine platens correctly and then operated in a proper manner.

This is obviously a function to be performed by the mould designer, and where it is a recognized procedure much serious damage as well as minor injury may be obviated, which will, of course, be reflected in reduced maintenance requirements.

In this connection it should be remembered that injuries may be done to a new mould by mishandling at the testing stages, which may not show up immediately but reveal themselves after a time to cause confusion to the repairer who may be searching for the cause.

Running-in.—Another very important factor of mould operation also of a general nature which deserves close atten-

tion is that of running-in the mould before working its output up to the maximum quantity.

Very often, if the sample mouldings produced from the first test of mould are considered satisfactory by both client and manufacturer, the mould then is stripped, blocks containing the matrices and other necessary members are hardened, ground and then finely polished, the mould then being reassembled for a further test. Should it pass this test satisfactorily, it is sound practice to run the mould at a very gentle rate for a period, gradually building up the output speed rather than attempt to reach maximum speed straightaway.

If there is great pressure on the tool-making department, or the client is clamouring for delivery of some components, etc., to mention two of the reasons often operating, this running-in stage is often drastically telescoped or even omitted altogether. Sometimes it is done for no other reason than the natural desire of all concerned in the manufacture of mould to ascertain exactly what it is capable of producing. Whilst such pride in workmanship and product is perhaps understandable, it is, nevertheless, dangerous practice and certainly one to be discouraged.

It is an action which is often the precursor of serious troubles, such as seized cores, ejector rods, scored mould cavities, sticking cores, warped blocks, stiffness in working mould, etc. It should always be borne in mind that a new mould will normally run much hotter and stiffer than one which has been in operation for some time, as every component is new and the degree of fit, or surface finish, requires just that minute amount of easement to cause smooth and ready operation.

Hence on this account alone operating difficulties will probably arise, the avoidance of which it is one of the chief reasons underlying the mould run-in.

Training of the Operator

Coupled with the practice of always having the mould designer present when a new mould is being tested, it should also be a similarly well understood part of shop procedure that when a tool-setter has installed a mould, whether new, or one that has been in use for some time, he should not leave the job until he is satisfied that the operator is fully capable of operating the mould in the proper manner without fear of causing it injury as a result of incomplete working instructions, lack of knowledge of the tool, or because of some misconceptions concerning the mould and its functioning.

Present-day conditions render this initial operator-training increasingly important. The plastics industry, like many others, has had to receive its share of completely unskilled labour, male and female. If an operator is not carefully coached in the safest and best manner in which to operate a mould, much harm may be done to the delicate or accurate tool, which may involve not only immediate and expensive repairs, but permanent injury likely to become a source of worry, expense and increased maintenance attention throughout the remainder of the mould's life.

It might pertinently be asked, what is it proposed such operator-training should comprise? Naturally this will depend to a large measure upon the degree of mechanical intelligence, experience and receptivity of the operator, and also upon the class of mould used.

Generally the operator should be clear upon all the following points which will serve to guide him in the proper use and care of the mould.

(a) Core withdrawing means. (b) Ejector mechanism operation. (c) Method of affixing mould blocks to machine platens, and nature of clamping. (d) Methods of lubricating. (e) Cleaning. (f) Cooling mould and care of water-circulating system. (g) Heating up, and mould temperature testing. (h) Curing time. (i) Features of a sound accurate moulding. (j) The positioning of insertion members to be moulded-in. (k) The various faults or errors in the finished moulding to be carefully indicated and explained so that the operator is aware of the undesirable features to detect or expect

during production. (1) Explanation of the working, purposes and possible snags in respect of any auxiliary mechanisms connected to mould, such as pneumatic core or ejector withdrawal, electric heating appliances for mould, and so on.

The object of such training should be to impress the need for care and understanding of the mould.

Daily Care During Production

Another useful part of operator training is that of imparting a nightly clean to the mould, a few minutes just prior to the stopping time being allowed for this purpose. He should clean down the mould, removing the effects of condensed steam, accumulations of surplus plastic material which normally tends to adhere on mould cores, in pockets of cavities, around ejector pins, and so on. Dirty lubricant should also be cleaned off. Water-cooling supply should be turned off and the water in channels drained. This latter is an important matter and if neglected is likely to lead to considerable maintenance trouble due to a reduction in the orifice of inlet hole and channels behind mould cavity, with resultant diminution of water-cooling effects. This will cause puzzling variations in the finished product and difficulties in mould temperature control, with frequent stoppages for cleaning and examination unless carefully checked.

It will be found that the few minutes entailed to carry out this or similar activities will make it possible for the operator to make a prompt start the next day in the assurance that the mould is properly clean, free from corrosion or rust on vital parts and such-like small snags, which in practice often combine to hold-up or retard production or may lead to mould breakdown.

Removal of a Mould When Production Has Ceased

The procedure to be followed by the tool-setter and tool-making section generally when production has terminated in respect of any particular mould should be well defined and invariably followed.

In many shops when a production run has been completed moulds are afforded very scrappy and indifferent attention if no known fault has been detected. The mould is usually given a very perfunctory external examination, it being hastily cleaned-up for such purposes by the operator or shop labourer, and then if adjudged satisfactory it is removed to the place of storage, to remain there without any further attention until the next time for its use arises.

Rather than such a practice it is preferable to insist upon the mould being removed from press platens by the same setter who installed it at the outset of production. The reason for this is that such a person will be more apt to detect signs of damage, difference in fixing, loss of screws, dowels, strained studs, and the like, all of which features easily and often develop during a long production run. He will know how the mould was initially fixed and thus will compare its position and condition at end of run.

The mould blocks should next be brought into the closed position and the complete tool, plus all auxiliary mechanisms, removed to the tool-room, or tool-repair section if the works is large and justifies such a separate unit.

Regardless of whether any fault, error, or unsatisfactory point has been reported or not the mould should be dismantled to the extent of removing ejectors, cores, holding strips, etc., so that all portions of mould construction can be carefully cleaned and examined by the mould engineer. Thus he will be able to detect signs of wear, tiny burrs, scratches or pittings on important mould surfaces. Points of strain, lack of lubrication, dirt or waste plastic accumulations and such like undesirabilities will be far more readily located and remedied.

Another object which will be secured by such action even though no fault is discovered, is that the mere act of removing dirt, foul lubricant, cleaning the members, and then re-lubricating them will of itself make for smoother running and increased life.

In the case of a mould thus dismantled

and examined and no serious trouble being revealed, after cleaning and oiling, it is reassembled and the mould cavities and other working parts given a coating of rust preventative or thick grease, and the mould blocks brought into the closed position. Water-cooling tubes external to mould blocks should be left unconnected for storage, as also external core drawing mechanisms. All such separate units should, of course, be tied to blocks and stored together with them. Screws or studs needed for fastening the mould blocks to platens should be threaded into the tapped holes in the mould, thus ensuring their being ready when the mould is next set up. These screws, incidentally, should also be examined for soundness of thread. As will be understood, considerable pressure and heat is imposed on these members, which might cause a stretching of the material, with a loosening of grip at that point, as a result of which the threads may become battered and, finally, in extreme cases stripped. In this respect, too, it will be a sound plan to measure up the length of screws to ensure that an adequate threaded portion passes into the mould block from machine platens to give a proper grip. It is surprising how a small item such as this can be varied over a period of working when unskilled persons are allowed to fix moulds in place or remove them.

This examination, cleaning and reassembly should be performed as soon after production has ceased as possible, as moulds removed from the machine and allowed to lie about on a bench or the floor or even in unsuitably constructed storage lockers are very prone to receive damage.

Particularly will this be the case if the mould is unassembled, as the separate members may then become a ready target for damage due to contact with other parts, tools, etc., or they may the more easily become misplaced and lost.

As regards storage, suffice it to mention that properly designed and constructed bins or shelves should be used, the shape and sizes of same being, of course, conditioned by the type and class of mould. Each mould, plus all auxiliaries, should have a permanent bin, in which it is always located and identified by some simple means. Whatever method of notation is employed, as well as indicating the locker or shelf, the mould should similarly be stamped in such a manner that there is no danger of the figures, etc., becoming covered over, obliterated, or rendered undecipherable from any other cause.

More will be written concerning storage facilities; it is sufficient to stress at this point the importance and necessity to have a properly laid-out, separately located storage-room in which all moulds are retained until actually required for production or else undergoing overhaul, and never should moulds be permitted to lie about in the production moulding shop unless required for immediate use.

Production Excess to Cover Waste

Some provision must be made to cover any scrap or waste made during subsequent machining operations on the finished mouldings, and, therefore, it is common precautionary practice at the end of a production run to mould a certain quantity of components actually in excess of the number stipulated on the order.

Should a mould develop errors or faults whilst this additional quantity of parts is being made there is a danger that the mould may be removed from the press, placed on one side, and another mould set up and the next order proceeded with, the faulty mould either being returned to stores or even left in the moulding shop. In such circumstances as these the risks of overlooking a fault correction are very great and special steps must be taken to ensure against such occurrences.

To overcome such difficulties it should be one of the recognized rules of moulding-shop procedure that no mould except those actually in production shall be permitted to remain in the moulding shop and also that all moulds which are returned direct to the stores for any reason shall do so only under the written authority of the moulding-shop foreman.

The latter personage, in the case of a mould which requires correction or repair, should also specify this information on a written document, which would then accompany the mould to the toolroom. Illustrations of a suitable type of docket employed for this purpose will be given in the second article of this series.

Procedure for Dealing with a Mould Needing Repair

Where a fault has developed in a mould and production is no longer possible, repairs will have to be performed; in these circumstances the mould should be removed from press and sent to the toolroom together with three or four mouldings, or sprays which have been produced at the end of the run, together with a few mouldings, etc., which are known to be correct. This is often of very great assistance to the toolmaker, and may afford him considerable guidance in determining the nature and cause of a particular error, which would not be so readily apparent from an examination of mould alone.

The urgency of the order will, of course, determine the degree of priority the mould has to receive when it reaches the toolroom, and the delivery date or other information indicating the urgency of repairs should be passed along to the toolroom at the same time as the mould is returned from moulding shop.

The writer has always found it a good plan to subject such a returned faulty mould to an immediate examination, the advantages to be gained from this are several. It enables the mould engineer to assess the scale of fault and the approximate length of time which will be required for repairing it, together with the number and cost of any parts needed as replacements. He will also gain a good idea of the extent of interruption in production which will be necessary.

Here again, in respect of any alterations, additions, modifications, corrections or replacements, complete details of the maintenance work performed should be recorded and copies filed away in both the general office and by the chief of the toolroom or repair department. Such a record will serve several useful purposes by indicating the maintenance cost incurred, the frequency of any particular fault, and production time lost due to repairs, and similar important data.

Use of Standard Components to Facilitate Repairs

On most plastic moulds, whether for the compression or injection process, there are a number of members which by reason of their shape, function and size, are readily capable of being standardized so as to be commonly applicable to most moulds.

Such mould items will consist of ejector rods, adjusting and locking nuts for same, binder screws, dowels, hardened guide bushes and pillars for ejector plates or strippers, return-pins, rollers, core-fastening screws, securing studs for mould shoes, sprue bushes, knock-out rail guides, gate and runner shape, sprue bush taper, and so on.

By affording a little consideration to such items it will be surprising how easily the mould designer or engineer is able to standardize in respect of lengths, diameters, and general shape. If this is accomplished it will be possible to make up quantities of all these components and to maintain adequate stocks available against breakdowns or the need for replacement of a worn part.

If this is done as part of the regular maintenance service much time will obviously be saved as such a standard part may be very quickly secured from stock, and fitted without much delay, in comparison to the steps required if a new non-standard component has to be manufactured and then fitted.

The designer will find it a great advantage if this matter of standardization of components of mould is carried out in a thorough-going fashion to the extent of reducing the number of different mould block dimensions so as to have a minimum number of block thicknesses. It will be a much simpler matter then to standardize on components within such a reduced range of block sizes.

When standardization has been developed, stock lists tabulating the requisite information should be issued for the guidance of draughtsmen and others.

By this procedure considerable detailing will be avoided, since the designer or repair department will requisition new parts by a reference number only.

Economic batch sizes can be selected for manufacture of all such standard parts, thereby deriving considerable machine-shop savings.

Another advantage to be gained from the development of standard units is that in case of slight faults due to wear, the replacement of the worn component may be effected without removing the mould from the machine.

In the case of moulds supplied to an outside firm, the ability to supply a standard component which it is known will uniformly replace a faulty part will prove a great help and time-saver because it will be possible to draw the item direct from stock of such standard parts immediately upon request, no delay being occasioned to the owner of the mould. He will also experience no difficulty in fitting the new component as it will be a replica of the one replaced.

A number of the more general features to be possessed by any scheme of planned maintenance service for moulds have now been discussed, which no doubt will illustrate the steps to be taken in order to place maintenance upon a sound and systematic footing. Design, construction and the treatment which a mould receives during production or storage are all very important factors conditioning the amount and seriousness of maintenance service which will be required.

Present-time labour and material difficulties make it still more necessary for taking every action possible to ensure longer life and smoother, trouble-free operation for all plastic moulds.

This can best be achieved by inaugurating a well-thought-out plan for servicing every mould by providing regular inspection, test, check, adjustment of minor troubles in order that such small faults, etc., shall be discovered, their causes revealed, and corrective action applied before they develop to more serious proportions leading to a production breakdown or a permanent injury to the mould.

In an ensuing article the subject of providing proper records for such a system of maintenance will be discussed.

(To be continued.)

" Mouldrite " Resins for Laminating

The most recent of the excellent series of technical bulletins on plastics brought out by I.C.I. (Plastics), Ltd., deals with the important subject of thermosetting resins for laminating. There are six resins (five phenol-formaldehyde and one urea-formaldehyde) in the range of I.C.I. laminating resins, some in alcoholic solution, others as aqueous solution, each with special attributes.

The manufacturing methods of impregnation are told in sufficient detail, and temperatures and pressures required are indicated. The methods described include considerable information on the production of decorative panels, laminated tubes and rods, compressed impregnated woods, shaped laminations, etc. In view of the growing interest of paper and fibre board makers in the use of synthetic resin, an excellent paragraph on the bonding and waterproofing of fibre board is included. In view of the absence of previous information on this subject we give the following details published in this bulletin:—

The addition of about 5 per cent. of thermosetting resin during manufacture of hard board gives improved mechanical strength and water resistance.

Resin 403 added in the form of an alkaline solution to the fibres at the beater stage is most suitable for this purpose. The solution is made by dissolving the resin in its own weight of a 40 per cent. solution of caustic soda in water.

After adding the resin solution, the mixture is brought to a pH of 5 by the addition of dilute sulphuric acid or aluminium sulphate, which precipitates the resin on to the fibres. The pulp is then filtered and hot-pressed at temperatures up to 135 degrees C.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XXIII.—Coating Media on Vinyl Acetate and Polyvinyl Alcohol Base (Contd.)

AS stated in the previous issue (April, 1944, pp. 193-198), the viscosity of the polymer and the value of conversion are dependent not only on the concentration of the ethyl acetate in the reaction mixture but also upon the quantity of catalyst.

Table 8 summarizes the experimental data on polymerization of vinyl acetate with varying amount of catalyst.

Table 8.

Amount of ethyl acetate to 100 parts by weight of vinyl acetate	Quantity of benzoyl peroxide, per cent.	Value of conversion per cent.			Viscosity, centipoises
		6 hours	8 hours	10 hours	
100	1	88.7	90.3	—	4.8
50	1	93.7	96.1	97.3	5.5
30	1	95.0	97.4	—	6.1
20	1	96.2	97.6	—	7.10
100	0.5	92.9	92.9	—	6.1
50	0.5	95.9	97.3	—	5.50
30	0.5	97.4	—	—	9.6
20	0.5	95.1	—	—	11.9
100	0.1	64.9	69	—	8.3
50	0.1	90.4	—	94	13.9
30	0.1	93.6	95.4	—	20.5
100	0.05	—	56.2	60.9	9.3
50	0.05	—	60.1	64.2	15.5
30	0.05	—	78.4	84.5	25.4
20	0.05	86	—	93.8	34.56

Thus it may be seen that the control of the viscosity of polyvinyl acetate can also be achieved by the introduction of different quantities of benzoyl peroxide.

As has been noted before, polyvinyl acetate is utilized in the production of spirit lacquers, enamels, as well as for obtaining the range of valuable synthetics designated as polyvinylacetals. The application of polyvinyl acetate in these cases is usually made in the form of a solution in ethyl alcohol (with viscosity from 2 to 15 centipoises). In this connection, therefore, it is appropriate to bring to light the question of the polymerizing vinyl acetate in ethyl alcohol. The result of experiments on this problem are summarized in Table 9.

Table 9.

Quantity of ethyl alcohol to 100 parts by weight of vinyl acetate	Amount of benzoyl peroxide, per cent.	Value of conversion, per cent.				Viscosity, centipoises
		5 hours	10 hours	15 hours	22 hours	
3	0.1	89	—	—	—	40.0
4	0.1	—	87.5	—	—	25.2
6	0.1	—	—	94.2	—	18.1
8	0.1	—	—	—	—	13.7
10	0.1	—	—	—	—	11.6
15	0.1	—	—	—	—	9.5
20	0.1	—	—	—	—	7.0
35	0.1	—	—	—	—	5.5
50	0.3	—	—	98.2	—	3.0
100	1.0	—	—	—	98.5	1.88

From the above it follows that polymerization in ethyl alcohol is a convenient method to obtain the polymers of low viscosity (that is, precisely those consistencies which are required in varnish manufacture and in the production of polyvinylacetale), and that the velocity of polymerization in presence of ethyl alcohol is somewhat lower than in experiments with ethyl acetate.

To obtain the characteristics of polymerization reaction of vinyl acetate in other available solvents, further experiments were conducted, using benzene and toluol (Table 10).

Polyvinyl acetate made by polymerizing the vinyl acetate in benzene, possessed a slightly higher viscosity than that resulting from the experiments using ethyl acetate. With toluol the viscosity is close to that when using ethyl alcohol.

Table 10.

Solvent	Quantity of solvent to 100 parts by weight of vinyl acetate	Viscosity, centipoises
Benzene	20	46.2
Benzene	30	32.1
Benzene	50	23.2
Toluol	20	5.9
Toluol	30	4.5
Toluol	50	3.6

With the aim of verifying the above data the Leningrad Plastics Research Institute has performed a series of large-scale experiments on polymerization of vinyl acetate in the presence of ethyl acetate as well as in the presence of ethyl alcohol. The reaction was carried out in an enamelled or nickel-plated autoclave fitted with a blade agitator and reflux condenser, using vinyl acetate distilled in a fractionating column 3.5 m. high. The quantity of vinyl acetate, which formed the charge in the reaction vessel, varied between 50 kilogs. and 130 kilogs. When conducting the polymerization in ethyl acetate, as soon as the reaction was completed, sufficient ethyl acetate was added to obtain a 50 per cent. solution of polyvinyl acetate. This solution then had a sufficient mobility to flow through the outlet.

The operating conditions and the results of some of the experiments, performed with catalysts, are shown in Table 11.

The resultant data with regard to the value of conversion and viscosity of polymer are found in perfect conformity with the regularities as established by laboratory studies. A somewhat lower viscosity of the polymer in comparison with the laboratory specimens may be explained by the inadequate purity of vinyl acetate. The ether content in vinyl acetate in this case fluctuated between 93.2 per cent. and 99.3 per cent.

To ascertain the influence of the materials of which the reaction plant equipment were made upon the polymerization process, special experiments on polymerizing vinyl acetate with the addition of ethyl acetate and alcohol in the presence of plates of aluminium, as well as chrome-nickel steel and chrome steel, were carried out. It has been found that the presence of these substances did not affect in any way either the viscosity, or the conversion value.

Production of Solid Polyvinyl Acetate

In certain instances it is required to prepare polyvinyl acetate not as a solution, but in the form of solid polymer.

With this object in view the polymerization has been conducted in solvent medium; the solvent was then removed by steam distillation, and the resulting polymer was passed through the outlet valve of the reaction vessel under pressure of about two atmospheres at the temperature about 90 degrees C.

By this method solid polymers with viscosities from 2.5 centipoises to 9.8 centipoises were obtained. In all these cases the polymer, after drying, was capable of being easily comminuted.

Conclusions

The purification and standardization of vinyl acetate to a degree required for its polymerization is easily attained by means of rectification.

For the production of polyvinyl acetate of various viscosities within the range from 8 centipoises to 58 centipoises, it is necessary to conduct the reaction in the

Table 11.

Solvent, in presence of which polymerization was carried out	Quantity of solvent to 100 parts by weight of vinyl acetate	Value of conversion, per cent.		Viscosity, centipoises
		6 hours	11 hours	
Ethyl acetate..	20	90.5	—	27.8
Ethyl acetate..	30	—	94.4	18.8
Ethyl acetate..	35	—	—	16.6
Ethyl alcohol..	100	—	—	2.4

presence of ethyl acetate, regulating the quality of the polymer by the amount of added solvent (keep the quantity of the catalytic agent constant).

The polymerization of vinyl acetate in ethyl alcohol affords the possibility of obtaining polymers with viscosity from 2 centipoises to 14 centipoises.

The solid polymer can be isolated by the removal of solvent by steam distillation with subsequent pressure release of the heated polymer from the vessel.

The foregoing experiments have confirmed the validity of the previously established dependence between the quantity of the catalyst, vinyl acetate concentration, duration of the reaction and degree of conversion (per cent.), as well as average molecular weight of polymer.

Use of Polyvinyl Alcohols

Polyvinyl alcohol, the synthesis of which has extensively been studied by Herrmann and Haehnel[367] and constitutes the subject-matter of many patents,[368] has found a wide and rapidly increasing application in industry either per se, or in the form of its various derivatives. Polyvinyl alcohol, with reactions typical of a polyalcohol, esterifying or etherifying its hydroxyl groups and condensing with aldehydes and ketones, etc., is thus obviously a material of promise, capable of yielding, under proper conditions, an almost limitless range of synthetic resins.

Apart from a special series of polyvinyl alcohols manufactured by Du Pont de Nemours and Co., U.S.A., a number of outstanding products has recently been issued in America by the Resistoflex Corp., designated as Resistoflex P.V.A., which, by combining flexibility, elasticity and resilience, i.e., low hysteresis with high strength properties, and unusual resistance to most organic solvents, as well as immunity to ageing, have already demonstrated their definite superiority over natural rubber. A very valuable range of processed polyvinyl alcohols, commercially known as Solvar, is made by Shawinigan Chemicals, Ltd., Canada, by means of partial hydrolysis of polyvinyl acetate;[369] the numbers associated with the term Solvar express the constitution of a given polyvinyl alcohol; for instance, Solvar 40/15 denotes the compound derived from Gelva 15, that is, polyvinyl acetate with a viscosity of 15 centipoises as determined in benzene solution, in which 40 per cent. hydrolysis was carried out.

In addition to markedly pronounced film-forming properties, polyvinyl alcohol solutions also yield adhesives of exceptional strength. The films prepared from aqueous solutions are not only able to withstand the action of the majority of the organic solvents, oils, alcohols, chlorinated hydrocarbons, etc., but are highly impermeable to gases, and display a strong resistance to oxidation and ageing induced by the actinic rays, to heat, and to ozone.

Behaving generally as reversible colloids, the polyvinyl alcohols proved to be very effective dispersing and emulsifying agents capable of forming an extremely important class of synthetic latices, characterized by their great stability. All who are familiar with coating technology can readily deduce from these characteristics the significance of such materials.

Of the various derivatives of polyvinyl alcohol the synthesis of polyvinylacetals is doubtless steadily occupying a more significant place, the treatment of which will be expounded in the next section.

(To be continued)

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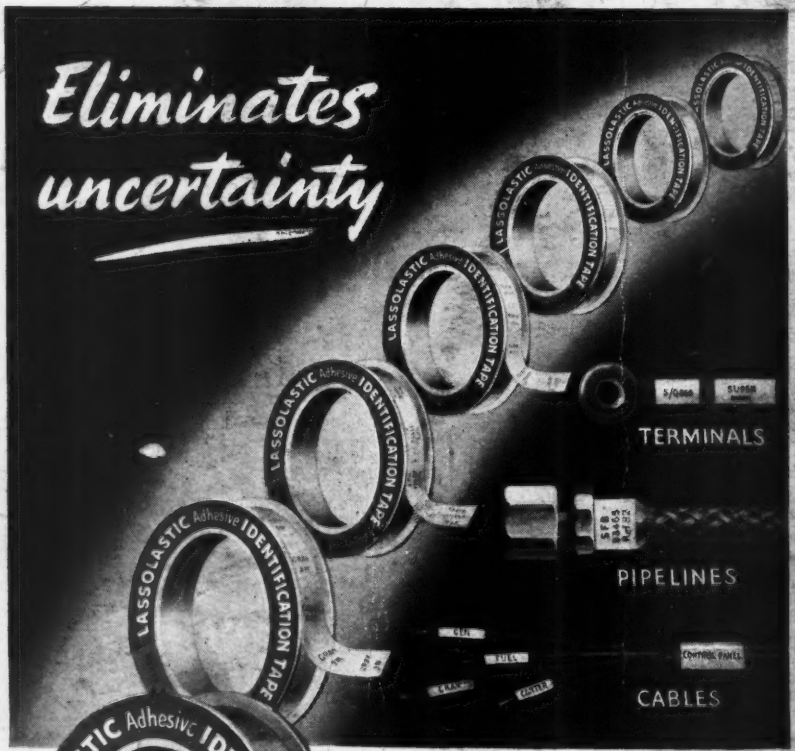

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